Report to the Okanogan & Wenatchee National Forests on the Results of the Frosty Creek Planning Area Fire History Research

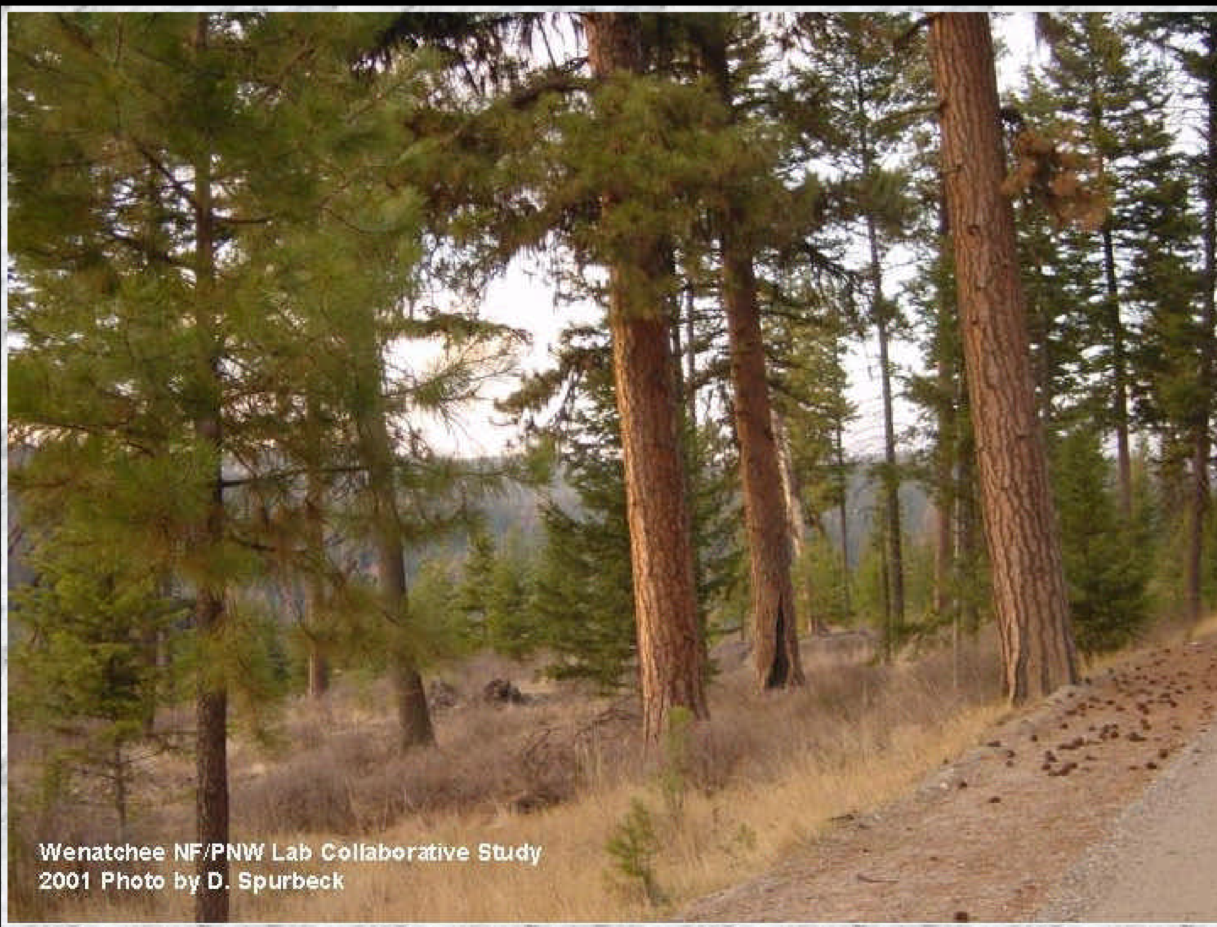

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX

ABSTRACT

The Frosty Creek planning area, located on the Okanogan and Wenatchee National Forests, was divided into eight polygons where a total of 190 individual fire years were cross-dated from 424 fire-scar samples. The dominant tree species are a mix of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) with lesser amounts of western larch (*Larix occidentalis*) and lodgepole pine (*Pinus contorta*). The earliest fire discovered was in 1343, however, the “period of reliability” (Touchan et al. 1996) dates from 1683 to 1917 (“pre-suppression era”). Weibull median fire frequency intervals (WMFFI) were uniform across most of the Frosty Creek planning area with analysis polygons averaging 7.4 years during this era. The average acreage burned in each fire within the sampled portions of the Frosty Creek area was 1,643 acres. Fires within sampled polygons typically burned from 27 to 62 percent of those areas. The largest fire was in 1812, burning 8,412 acres or 81% of the eight sampled polygons. There were 19 large fires that burned greater than 25% of the total sampled area during the pre-suppression era. After 1917, there has been a dramatic change in the fire regime in sampled polygons with only two recorded fires burning a total of 151 acres.

Approximately 20% of the Frosty Creek planning area contains more mesic sites where a mix of Douglas-fir, western larch, lodgepole pine, Engelmann spruce (*Picea Engelmannii*), and subalpine fir (*Abies Lasiocarpa*) were found. These areas experienced a pre-suppression era MFFI of 40.2 years and are reported independent of Polygons 1 through 8.

1. INTRODUCTION

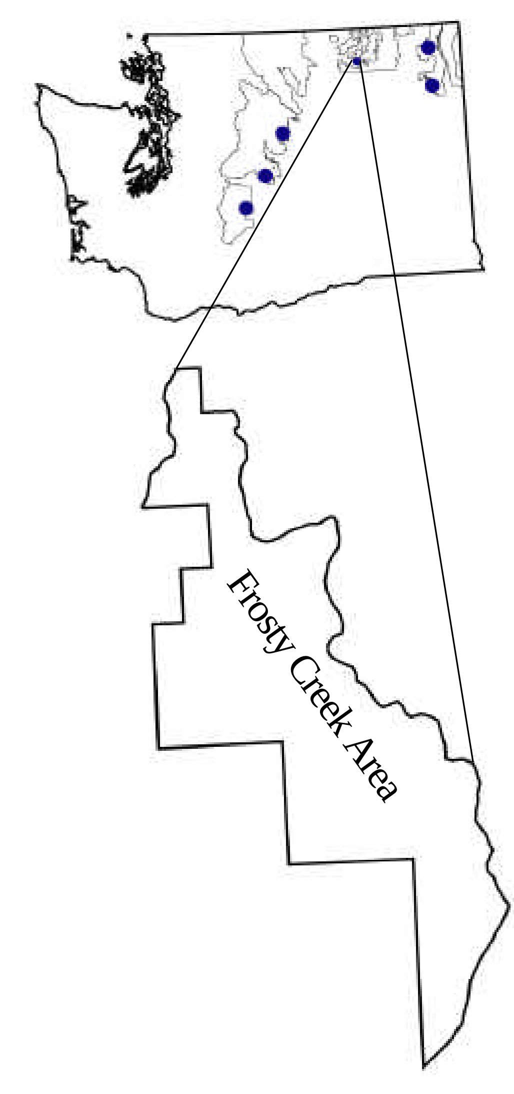

Figure 1. Frosty Creek planning area's location among five other fire-history sites examined by Everett et al. 2000, Schellhaas et al. 2000a & 2000b, and Keenum (in prep.) on the Colville, Okanogan, and Wenatchee National Forests.

The historical fire regimes were analyzed in the Frosty Creek planning area of the Tonasket Ranger District. The entire planning area is 14,215 acres in size, of which 13,338 acres (94%) is under Forest Service ownership. The area is located in north-central Washington state, south of U.S. Highway 20, directly east of the Aeneas Valley, and approximately 10 miles west of the town of Republic (Figure 1).

The Frosty Creek planning area includes portions of the Cape Labelle, Frosty, Coby, and Ogle Creek drainages. Elevations range from 3,400 to 5,600 feet. Forest types are dominated by a mix of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) with lesser amounts of western larch (*Larix occidentalis*) and lodgepole pine (*Pinus contorta*). On north aspects, higher elevations, and where cooler more mesic conditions exist, Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are also found.

Fire history is a function of forest type, topography, microclimate, ignition source, and past disturbance history. Knowledge of fire history provides insight into stand structure and species composition that likely existed historically. Land managers can use this information to create, restore, and maintain sustainable vegetation patterns. The inherent fire disturbance regime is an important reference point to assess changes in vegetative patterns and the associated risks to catastrophic fire that have resulted from livestock grazing, timber harvest, and decades of fire suppression (Finch 1983, Agee 1994, Ohlson 1996, Wright 1996, Everett et al. 2000, Schellhaas et al. 2000a & 2000b, Keenum [in prep.]).

Research on the Colville, Okanogan, and Wenatchee National Forests has shown that stand structure and species composition in ponderosa pine, Douglas-fir, and grand fir (*Abies grandis*) forests have dramatically changed as inherent disturbance regimes have been altered (Finch 1983, Agee 1994, Ohlson 1996, Wright 1996, Everett et al. 2000, Schellhaas et al. 2000a & 2000b, Keenum [in prep.]). As forests in these vegetation series have progressed further along successional trajectories, fire regimes have changed from frequent low or mixed-severity towards a less frequent, but higher-severity (stand-replacement) pattern.

The goal of this analysis was to describe historical fire regimes in terms of frequency, extent, and severity to provide information that will assist forest planners in future management. These results will also fill a spatial gap and link a series of fire-history studies completed in other forests of eastern Washington, extending from the Colville National Forest to the southern end of the Wenatchee National Forest (Figure 1). In addition, these data will be analyzed as part of a regional fire/climate project in cooperation with the University of Washington.

2. FIRE HISTORY TERMINOLOGY AND CONCEPTS

Researchers report results of fire history studies using specialized terminology. Without an understanding of fire history terms and concepts, it can be difficult to interpret the results of a study, compare results from different studies, or develop management options based on the results.

2.1 Fire Frequency

Fire interval, fire-free interval, and fire-return interval are three synonymous terms that refer to the number of years between two successive fire events in a given area. The arithmetic average (mean) of all fire intervals in a given area over a given time period is referred to as the mean fire-return interval or mean fire-frequency interval (MFFI). This metric is the one that has commonly been used to characterize fire regimes and is based on an underlying assumption, not necessarily correct, that fire return intervals are distributed normally. Grissino-Mayer (1995a) suggests that the Weibull median fire frequency interval (WMFFI) is a more accurate metric for characterizing fire regimes when fire frequency distributions are skewed (the distribution curve is not normal or bell-shaped). For this study, we have chosen to follow the terminology used in the FHX2 fire history analysis software developed by Grissino-Mayer (1995b).

2.2 Point vs Area Estimations of Fire Frequency

Another concept necessary to fully comprehend and compare reconstructed fire histories is the difference between point-based and area-based fire frequency. The following definitions of point and area frequencies were taken from Agee (1993). A point frequency is the mean fire interval at a single point

(an individual scarred-tree) on the landscape. In practice, point frequencies are usually expanded to include data from several proximate scarred trees because a single tree may not always record every fire and succeeding fires may burn off older scars. Agee (pers. comm.) recommends sampling three to five scarred trees in close proximity (within < 3 acres) to derive an accurate estimate of fire frequency at an individual location. An area frequency represents the mean interval between fires that burned some portion of, but not necessarily the entire sampled area. Successive fires within an area may overlap slightly, entirely, or not at all. Point-based estimates of fire intervals are generally larger (longer periods between successive fires) than those derived from area estimates (Kilgore and Taylor 1979).

Ecological implications (fire effects) can be confounded by reporting a fire frequency but neglecting to mention if the estimate is based on data from a single point or from across a large landscape. Knowing the size of the area on which the estimated fire frequency is based is critical; as the size of a sampled area increases, fire frequency generally decreases. In fact, there are existing studies that report MFFIs of less than two years (Kilgore and Taylor 1979, Dieterich 1980). These estimates are based on fire scars collected across very large landscapes. Estimates of area fire-frequency taken from samples collected across large landscapes are generally not suitable for inferring ecological processes based on the effects of recurring fires. Actual fire frequency at any specific point on these large landscapes is much longer than two years. Again, area frequencies reflect the incidence of fire somewhere, but usually not everywhere, within the sampled area. Variability associated with fire frequency within an area becomes more pronounced as the sampled area increases in size or heterogeneity (i.e. topography, forest types, aspect, etc.), with some areas experiencing fire frequencies much higher or lower than the mean. In contrast, point-based estimates of fire frequency, especially when corroborated by multiple scar samples taken from several adjacent trees, provide specific information

about the periodicity of recurring fires and the effects of those fires at a known point on the landscape.

2.3 Fire Regimes

A fire regime is a complex system of cycles and patterns of fire influenced by factors including species composition (overstory and understory), topography, and climate. All the factors of a fire regime are expressed in how often fire occurs, how large a fire grows, how intense a fire gets, and how severe a fire becomes. Intensity refers to the heat and duration produced by a fire while severity refers to a fire's effect on vegetation (Agee 1993).

A regime is complicated by the varying degrees of frequency, size, intensity, and severity that can occur but in general, three types of fire regimes are recognized based on the outcome of the regime: low-severity [non-lethal], mixed-severity, and high-severity [lethal] (Agee 1999). Here the "non-lethal/lethal" attribute refers to fire's effect on the overstory component of a forest.

Low-severity regimes are typified by fire-tolerant tree species with thick bark and open crowns. In the Pacific Northwest these species primarily include ponderosa pine and western larch. Forests within the low-severity regime are drier and have frequent, low-intensity fire which maintain an open "park-like" appearance (Gorman 1899).

High-severity regimes usually are the result of longer time periods between fires. These longer intervals allow for denser forest structure, the establishment of fire-intolerant species, and higher fuel accumulation that result in lethal stand-replacing fires. Species composition here tends toward later successional stages within wetter forests.

As the name implies, mixed-severity regimes are typified by a combination of low-severity and high-severity fires. This regime is the most complex of all resulting in fragmented landscapes in varying degrees of succession. Normally, areas experiencing the higher-severity burns were in moister/cooler areas with longer fire return intervals (i.e. riparian areas, north-facing slopes, higher elevations). This contrasts with drier, warmer areas where frequent fire curtailed tree density and fuel buildup and lower fire intensity maintained overstory trees.

Note that the above description of fire regimes is meant to be viewed on a landscape level and that it should be recognized that both low or high-severity fire can occur at any one point within the landscape, under any regime.

3. METHODOLOGY

3.1 Sampling Design

Previous studies have subdivided landscapes into homogeneous landtypes to assist the fire-history description and reduce statistical variability (Everett et al. 2000, Schellhaas et al. 2000a & 2000b). Gentle topography and the single predominant exposure of the Frosty Creek area made it difficult to stratify into well-defined landtypes based on varied aspects and percent slopes. However, polygon boundaries are generally based on topographic features that maximize landscape homogeneity and the probability of a common historical fire disturbance across the area. This stratification also assisted in the analysis by subdividing this large area into smaller organizational units. We divided the area into eight analysis polygons that ranged in size from 550 to 2,237 acres with a mean size of 1,294 acres (Figure 2).

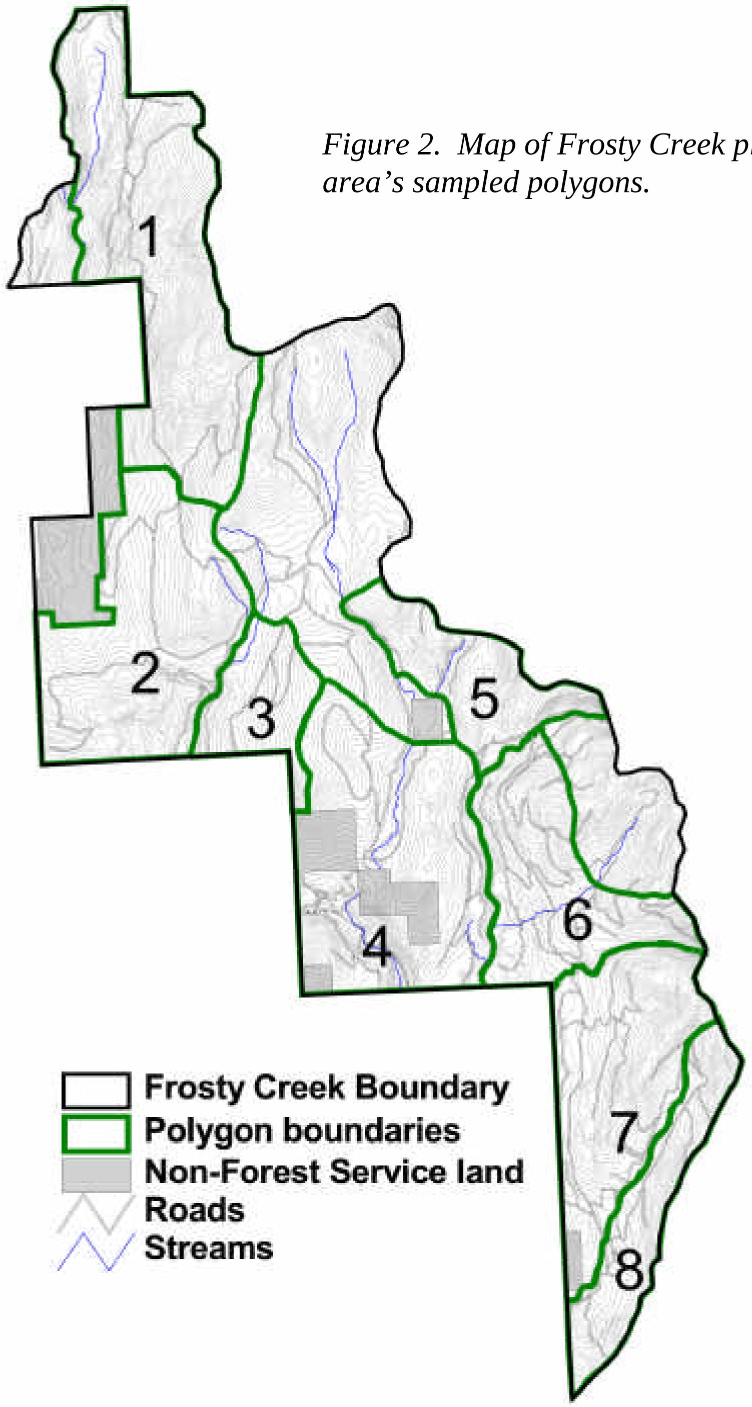

Figure 2. Map of Frosty Creek planning area's sampled polygons.

3.2 Field Methods for Master Chronology and Fire History

Data for this fire history were collected during the summer and fall of 2001 on National Forest land within the Frosty Creek planning area. The area was intensively searched for evidence of past fires from fire-scarred trees, snags, logs, and cut-stumps in all stand types. On living fire-scarred trees and snags, wedges containing the fire scars were extracted using the methods described by Arno and Sneck (1977). Samples from logs and stumps were sectioned to ensure collection of the maximum number of fire-scar events. Whenever possible, multiple samples in close proximity were collected to develop point fire-frequency intervals. Locations of fire-scarred samples were geo-referenced and entered into a (GIS) database for subsequent mapping of fire locations and fire extent.

Where direct evidence of past fires was scarce, remnant live-trees (those remaining following a fire) and early seral tree species were located and increment cores obtained to infer and extend the fire history record through cohort analysis (sensu Heinselman 1973, Oliver and Larson 1996). In all, 424 fire-scarred samples with an additional 78 increment cores were collected (Figure 3). Of these 78 cores, 48 were from climatically-sensitive trees chosen to develop a master chronology to aid in cross-dating. Cross-dating is the process of matching variations in tree-ring widths or other ring characteristics among several samples, allowing the precise year of each ring to be determined (Kaennel and Schweingruber 1995).

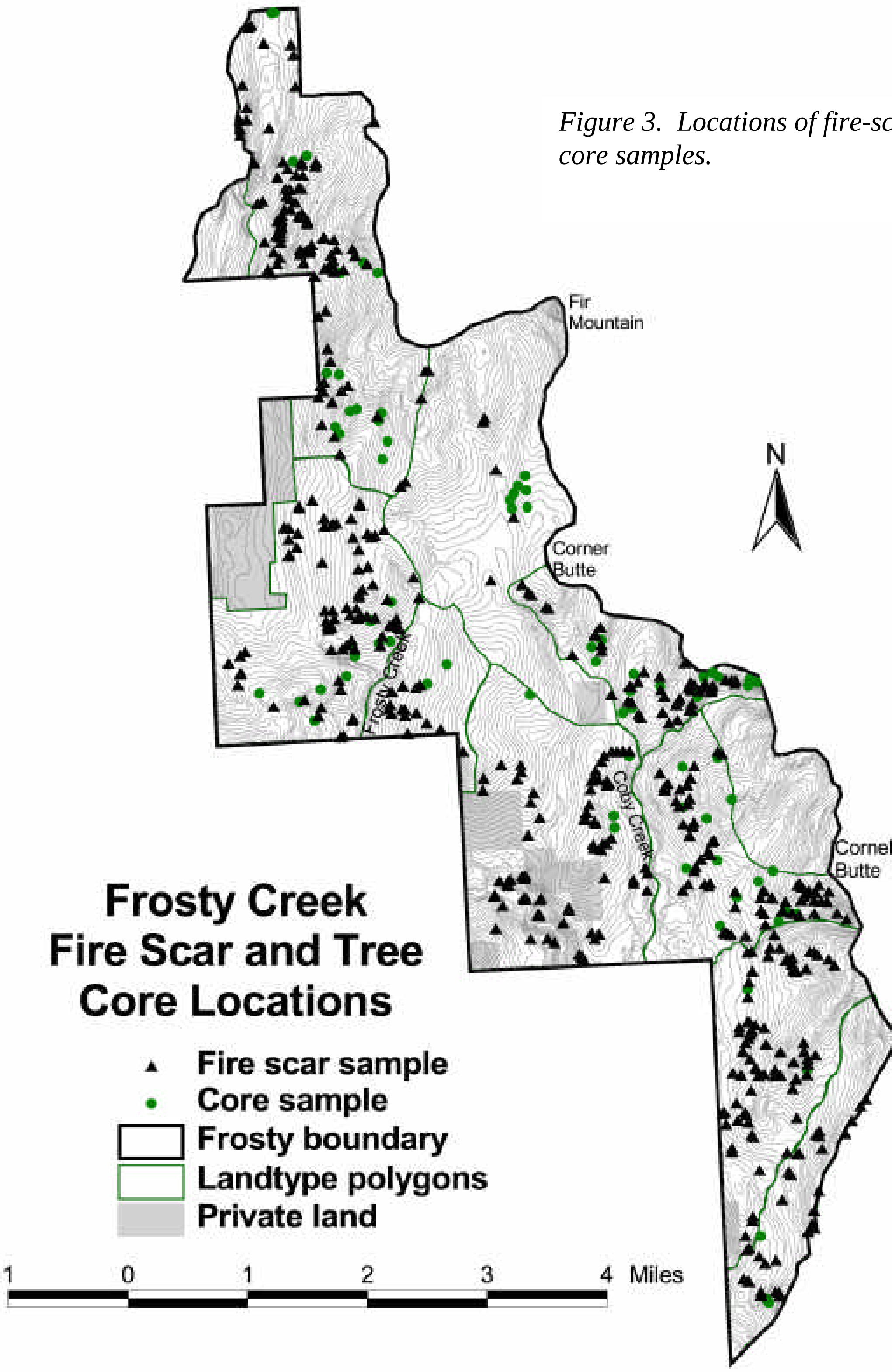

Figure 3. Locations of fire-scar and tree-core samples.

3.3 Laboratory Preparation and Analysis

Determining the exact year of a fire through cross-dating depends on developing an accurate master chronology, or time series of tree-ring widths in which the climate signal is maximized (Stokes and Smiley 1968, Fritts 1976). Tree growth on dry, rocky outcrops in the Frosty Creek area is limited by available soil moisture, which changes in response to annual precipitation. The 48 sampled cores are from trees growing on these harsher sites and have well-defined narrow-growth rings in dry years and distinct wide rings in wet years.

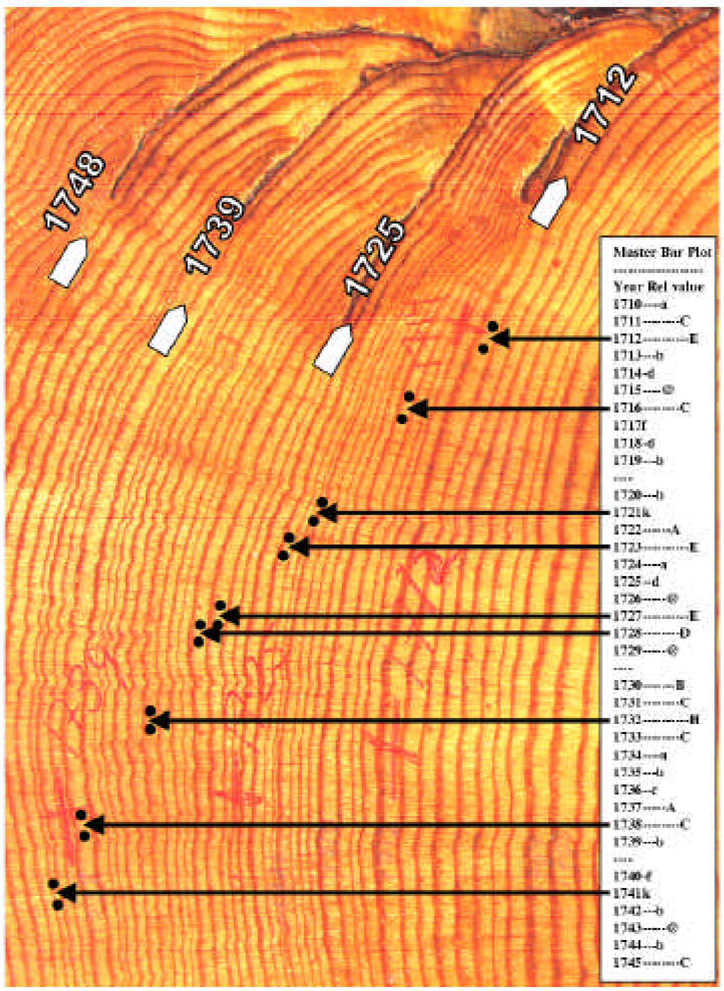

Figure 4. Part of the output of the computer program COFECHA is a "Master Bar Plot" of relative tree-ring widths (a segment is shown above). The bars show the relative width of each year's ring with the longer the bar, the wider the ring. Lower-cased letters signify rings narrower than the local mean while upper-cased letters represent rings wider than average. Note how the wide and narrow rings shown on the bar plot match ring patterns on the fire-scar sample (black arrows) enabling precise fire years to be established (white arrows).

Building the master chronology involved measuring each ring from the 48 climatically-sensitive tree-cores on a Velmex sliding-stage micrometer with Acu-Rite encoder using

MeasureJ2X software (2001). The tree-ring measurements were then validated for dating accuracy with the COFECHA software program (Holmes et al. 1986) that also produced a graphical master chronology of tree-ring widths representing wet and dry years (Figure 4) analogous to the skeleton plot described by Stokes and Smiley (1968). There was an exceptionally robust inter-correlation (0.675) between the measured tree cores that resulted in an extremely accurate master tree-ring chronology. This chronology included the period from 1599 to 2000 where signature years and recognizable patterns of years were used to cross-date fire scars on each sample and assign the correct calendar year to each scar (Figure 4) (Madany et al 1982, Dietrich and Swetnam 1984, Brown and Swetnam 1994, Grissino-Mayer 1995a). Cross-dating was facilitated by developing a list of marker years (Yamaguchi 1991) that could be readily identified on many of the fire-scar sections.

Each fire-scar cross-section was sanded with a succession of sandpapers, ending with either 320 or 400 grit to allow reading of extremely small growth rings. Some of the sections cut from snags and logs were partially rotten and required extensive re-construction before they could be sanded and their fire scars dated. Fire scars from live trees and dead wood were dated by visually comparing ring patterns with those in the master chronology.

Once each fire scar was assigned a date, these data were analyzed using the FHX2 software package (Grissino-Mayer 1995b). The arithmetic mean and Weibull median fire-free intervals were computed utilizing the polygon area and point-frequency methods. Along with the Weibull median interval computed for each polygon, Weibull Exceedance Probabilities were computed at ($\alpha = 0.125$) to document any statistically-significant short or long intervals that may be present (Grissino-Mayer 1995b). Grissino-Mayer recommends the less stringent 0.125 statistical-level instead of the usual 0.05-level when making ecological interpretations based on fire-history data. Fire chronologies were assembled for each polygon and for the entire planning area. We sorted point-sample locations

by aspect, slope class, elevation class, and topographic position for separate analysis to ascertain if topographic attributes had any affect on fire frequency. Point and polygon fire-frequency were compared with “t” tests of difference using the 0.05 level of significance (Little and Hills 1978).

Severity and intensity of fire can be inferred by the abundance of fire-scarred trees (Agee 1993) particularly those enduring multiple fires. In addition, a measure of tree diameter when scarring first occurs strengthens conclusions of fire magnitude (Wright 1996, Everett et al. 2000, Schellhaas et al. 2000a & 2000b, Gray et al. 2002). When piths from fire-scar samples were present and the first scar had not been damaged by succeeding fires, we measured the diameter of the tree when this initial scar occurred to the nearest 0.1-inch and recorded its age.

Spatial distribution of each fire is displayed through a set of fire extent maps generated from geo-referenced locations of fire-scarred cross-sections (Agee et al. 1986). Maps of these fire perimeters are shown on the individual fire year maps in the appendix. In addition to direct fire-scar evidence, we utilized tree core and fire-scar samples exhibiting aberrant ring-patterns that correlated with established fire years. These data further reinforced the established perimeter of fire extents when located within the fire boundary. When this indirect evidence was located outside but adjacent to established fire perimeters, we estimated extensions of fires (shown on the fire extent maps in the appendix). These extensions are for areas likely to have burned, but evidence of this is less certain than for areas based solely on fire-scarred samples. Reported fire sizes reflect the more conservative direct-scar estimate.

Fire boundaries were developed using criteria similar to those used by Hemstrom and Franklin (1982) where we made the following assumptions:

1. A fire starting within the general area of where the samples were collected would spread until encountering a topographic or fuel barrier.

2. Fire spread was in an uphill direction.
3. Fire boundaries were conservatively estimated; perimeters were not extended beyond the evidence of fire scar or cohort data except by rules 1 and 2.

3.4 Spot Fires

Some lightning ignitions may yield insignificant fires that scar only one or a few trees and we refer to these as spot fires. We feel that including spot fires in fire frequency calculations disproportionately affect area fire frequency since resultant ecological impacts are negligible. With this rationale in mind, we have chosen to exclude spot fires from fire frequency analysis at all levels (i.e. planning area, polygon, and points). Spot fires do not appear on fire extent maps and are not included in area-burned summaries. For the purpose of this report, we describe a spot fire as one that is only recorded by a single fire-scar. Additionally, single fire-scars that were spatially isolated from a larger fire-perimeter were also excluded from frequency and extent calculations. The distribution of spot fires and the year in which they occurred are included in Figure 5.

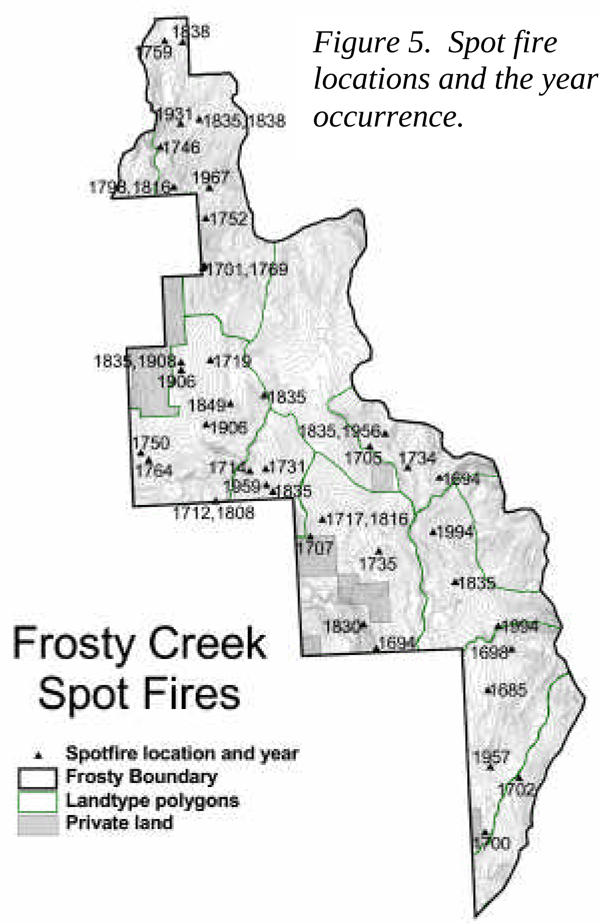

Figure 5. Spot fire locations and the year of occurrence.

4. RESULTS AND DISCUSSION

4.1 Time Periods

A total of 190 individual fires were cross-dated from the 424 scar samples that were collected. The earliest fire we were able to document within the Frosty Creek Planning Area occurred in the year 1343. We also documented fires from the fifteenth and sixteenth centuries. The exceptionally large number and quality of fire-scar samples collected, enabled us to reconstruct the fire history of much of the sampled portion of the Frosty Creek planning area back to the year 1683. This date is the beginning of the “period of reliability” when each polygon contained at least three sample recorder-trees (trees scarred by fire) (Touchan et al. 1996). Although we were able to document some very old fire events, the number of surviving fire-scar samples from the 14th, 15th, and 16th centuries was too small to infer fire frequency or size with the same degree of accuracy as the post-1683 period.

Finch (1983), working in forests near Frosty Creek, reported increased fire frequencies during the 1800s that he attributed to anthropogenic burning. Unlike Finch, we were unable to detect any changes in fire frequencies that could be ascribed to this source. Historical lightning-caused and Native American ignitions are practically impossible to distinguish and are beyond the scope of this study. Everett et al. (2002) and Barrett and Arno (1982) have found an increase in fire frequency near major valleys and speculate this may be the result of Native American activities. The increase observed by Finch may have actually been due to the effects of Euro-settlement.

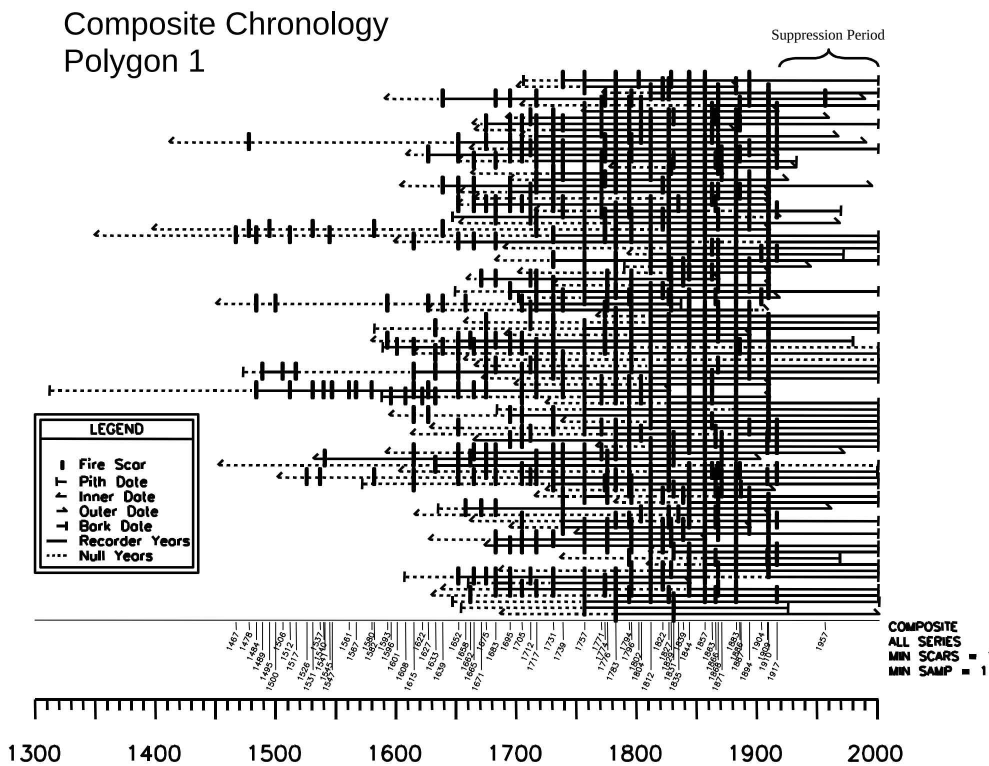

Figure 6. Example composite chronology of fire history generated by FHX2 software (Grissino-Mayer 1995b). Eighty-seven fire-scar samples are represented by horizontal lines with short vertical bars marking fire years. An obvious break in the pattern of fire occurrence takes place in Polygon 1 after 1917 when effective fire suppression was instituted.

Impacts of settlement on fire regimes beginning in the late 1800s ("settlement era") that have been observed in other fire history studies in eastern Washington (Everett el al. 2000, Schellhaas et al. 2000a & 2000b) was not apparent in the Frosty Creek area so we chose not to separate this period. Consequently, our analysis of fire history is divided into only two time periods: 1683-1917 and 1918-2001. We refer to these time periods as the "pre-suppression" and "suppression" eras, respectively. The 1917 cutoff date was chosen as we observed through our fire history analysis that an abrupt change in fire frequency (Figure 6) occurred following that year. These changes have also been documented across the western United States at about this same time and likely result from a combination of factors including livestock grazing, timber

harvest, and active fire suppression that significantly altered inherent fire regimes (Agee 1993, Arno 1988, Arno et al. 1997, Barrett 1988, Everett et al. 2000, Grissino-Mayer and Swetnam 1995, Parsons and DeBenedetti 1979, Schellhaas et al. 2000a & 2000b, Wright 1996).

4.2 Fire-Free Intervals (Polygons 1 through 8)

There were not enough fires to compute the WMFFI statistic during the suppression era, but as both statistics do not differ to any great extent, use of the MFFI statistic for management decisions is appropriate. However, the following discussions are limited to using only the WMFFI metric. Table 1 displays point WMFFI, area WMFFI with range and exceedance probabilities, and area MFFI for the pre-suppression period.

4.2.1 Area Frequency

The pre-suppression WMFFI for the entire sampled portion of the Frosty Creek area was 2.4 years. As previously described, these numbers reflect that on average; there was a fire somewhere within the sampled area every 2 to 3 years. During the suppression era the overall MFFI was 42.0 years.

Although it is interesting to know that fires burned somewhere within the planning area every 2 to 3 years during the pre-suppression era, knowledge of the frequency of disturbance across smaller areas is more useful from a management perspective. Accordingly, we reconstructed the fire histories for each of the eight polygons (Table 1). The mean pre-suppression WMFFI for Polygons 1 through 8 was 7.4 and ranged from 4.7 years in Polygon 4 to 11.4 years in Polygon 6. Statistically, area WMFFI for Polygon 6 is significantly longer ($\alpha = 0.05$) than all except Polygons 3 and 5. WMFFI for Polygon 4 is significantly shorter ($\alpha = 0.05$) than all polygons except Polygons 1 and 2.

Finally, WMFFI for Polygon 2 is significantly shorter (α = 0.05) than Polygons 3, 5, and 6.

Table 1. Fire frequency summary within polygons for Frosty Creek planning area.

Polygon #	Area Name	1683 - 1917				
		Point WMFFI	**Area MFFI**	**Area Range**	**Area WMFFI**	**Weibull Exceedance Probability Range**
1	Cape Labelle Cr.	13.6	6.5	1-18	5.7	2-8
2	Frosty Cr. West	10.7	6.0	1-18	5.4	2-8
3	Frosty Cr. East	15.3	9.7	3-24	9.0**a**	4-14
4	Gooseberry	13.5	5.3	1-21	4.7**b**	2-7
5	Corner Butte	16.7	10.3	2-36	9.2**c**	3-14
6	Coby Cr.	17.4	12.4	2-28	11.4**d**	6-19
7	Ogle Cr.	12.6	7.0	2-15	6.5	3-10
8	Coco Mtn.	12.4	7.7	2-15	7.0	4-10
	Mean	**14.02**	**8.11**	**1-36**	**7.36**	**2-19**
	SD	**2.31**	**2.45**	**-**	**2.30**	**-**
	CV	**0.16**	**0.30**	**-**	**0.31**	**-**
1-8	**Entire area**	**13.74**	**2.92**	**1-8**	**2.41**	**-**

a *– Weibull median FFI for Polygon 3 is significantly longer than Polygons 1, 2, and 4.*
b *- Weibull median FFI for Polygon 4 is significantly shorter than all other polygons except Polygons 1 and 2.*
c *- Weibull median FFI for Polygon 5 is significantly longer than Polygons 1, 2, 4, and 7.*
d *- Weibull median FFI for Polygon 6 is significantly longer than all other polygons except Polygons 3 and 5.*

(0.05 level of significance)

4.2.2 Point Frequency

Figure 7 displays the 88 locations for which we derived point-based estimates of WMFFI. The point-based estimates were, as expected, generally longer than the area-based estimates, ranging from 8.6 to 19.7 years with a grand mean of 13.7 years and coefficient of variation of 0.22. The time periods for which point estimates of WMFFI are based vary among points, reflecting

differences in the quality and availability of scar samples at each point. There was more variation at individual points than at polygons on the landscape (Table 2 in appendix) where we found a minimum interval of 2 years and a maximum interval of 47 years.

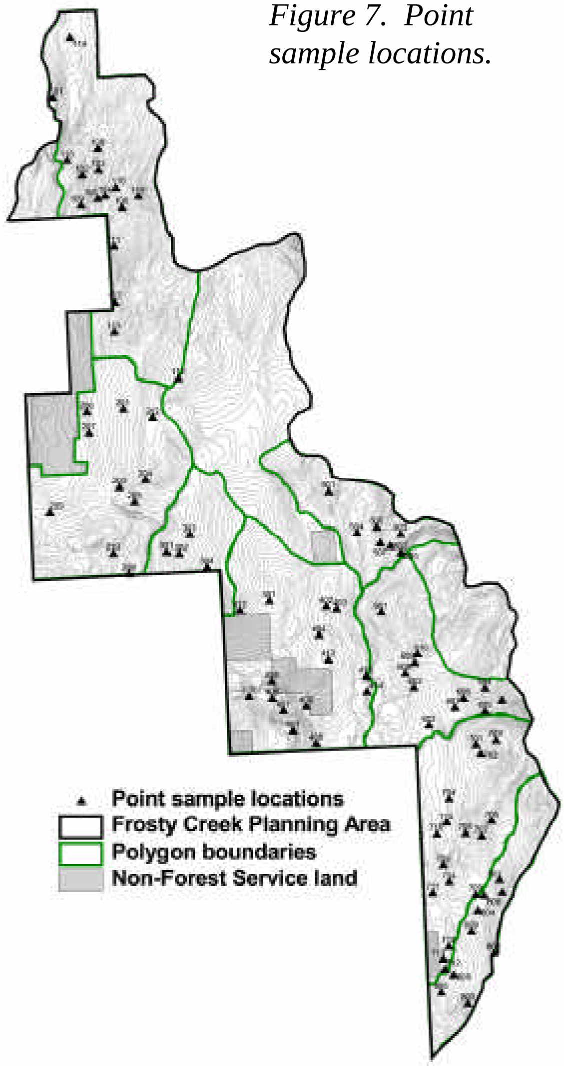

Figure 7. Point sample locations.

Point fire-frequency was generally uniform across all topographic attributes. Mean frequencies ranged from 12.5 to 14.5 years by aspect, 12.6 to 14.1 by elevation class, 13.5 to 14.5 by slope class, and 13.0 to 14.1 by topographic position for individual points (Figure 8 in appendix). The only statistical significance was between north and south slopes but this difference (14.5 and 12.5) may be ecologically unimportant. This variation may be attributable to a limited sample size among north facing aspects.

4.3 Fire Extent (Polygons 1 through 8)

The estimated number of acres burned within the sampled portion of the area each year since 1683 is shown in Figure 9. The average percent a polygon burned in a single fire event (Table 3) ranged from 27% in Polygon 4 to 62% in

Polygon 6. Mean fire size within Polygons 1 through 8 was 1643 acres, with a range of 20 to 8412 acres.

Estimates of actual, as opposed to within-polygon, fire size ranged from a 20-acre fire in 1808 to a fire that burned 8,412 acres or 81% of the sampled portion of the planning area in 1812 (Table 4 in appendix). The series of maps in the Appendix show locations and estimated sizes of fires for each of the years in which we documented fire activity within the Frosty Creek planning area. Because fire sizes were conservatively estimated and include only the portion within the Frosty Creek area, excluding private lands, the actual fire sizes were likely to have been somewhat larger than our estimates. Of the 78-recorded fires

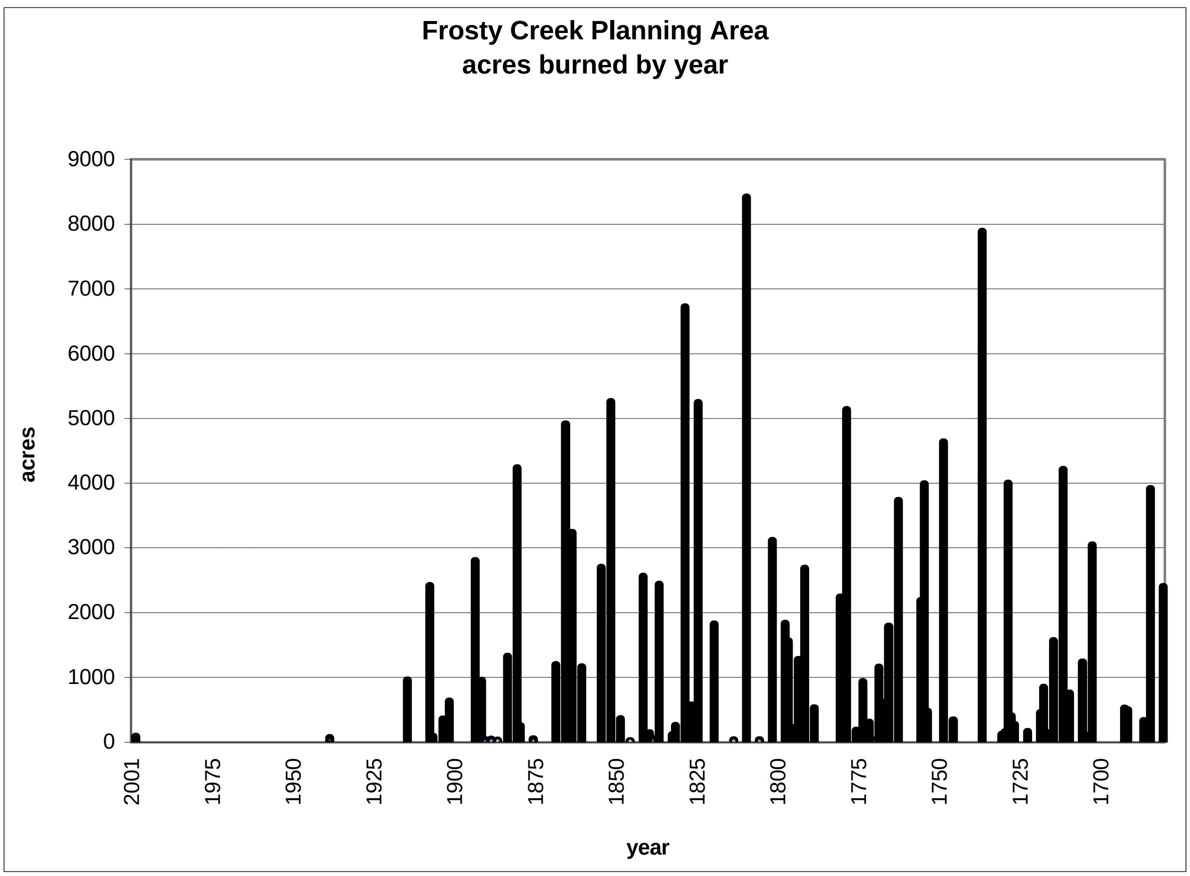

Figure 9. Fire size (acres) by year for Frosty Creek planning area from 1683 to present.

during the pre-suppression era, 19 of these were considered large fires (burning a minimum of 25% of the total planning area on average every 11.6 years) (Everett et al. 2000).

Table 3. Summary of fire size (acres) within the polygon and mean percentage of the polygon burned for the Frosty Creek planning area.

Polygon	1683 - 1917				
	Total Acres	Mean Acres Burned	CV	Range	% Burned
1. Cape Labelle Cr.	2236	772	.74	9-2104	35
2. Frosty Cr. West	1760	562	.76	20-1292	32
3. Frosty Cr. East	549	166	.62	20-303	30
4. Gooseberry	1723	457	1.05	20-1512	27
5. Corner Butte	761	368	.74	33-753	48
6. Coby Cr.	1180	735	.61	28-1180	62
7. Ogle Cr.	1376	695	.75	21-1376	51
8. Coco Mtn.	760	453	.64	9-758	60
Polygons 1-8	**10,345**	**1643**	**1.16**	**20-8412**	**16**

To ascertain if topographic features historically served as firebreaks, we computed Jaccard Similarity Indices (JSI) between pairs of adjacent polygons separated by either a valley bottom or a ridgeline and between non-adjacent polygons (Table 5). A higher Jaccard Similarity Index indicates that the polygons being compared shared similar fire events and thus the topographic feature separating the polygons was not effective in stopping spread of fire between the polygons. We found the highest indices for Polygon's 7 and 8. These polygons are adjacent and separated by a drainage, indicating that this topographic barrier was not effective in halting the spread of fires between these two polygons. It was also observed that many more fires burned across other apparent topographical-barriers that were not located along polygon boundaries suggesting the lack of effective natural fire-breaks within the Frosty Creek area.

Table 5. Fire year synchroneity (Jaccard index) between polygons within the Frosty Creek planning area (1683-1917).

Polygons	% Similarity	Polygons	% Similarity
1-2*	51	3-5	24
1-3	26	3-6	22
1-4	28	3-7	26
1-5	14	3-8	25
1-6	10	4-5*	29
1-7	30	4-6*	28
1-8	29	4-7	32
2-3*	41	4-8	27
2-4	47	5-6*	41
2-5	22	5-7	28
2-6	14	5-8	27
2-7	28	6-7	44
2-8	25	6-8	32
3-4*	49	7-8*	70

**Adjacent polygons*

4.4 Areas of Mixed-Severity

Approximately 20% of the Frosty Creek planning area lacked sufficient data for detailed analysis and is reported here independent of Polygons 1 through 8. Areas southwest of Fir Mountain and northwest of Cornell Butte produced minimal or no fire-scar evidence. This lack of fire-scar samples here only allows for ambiguous fire extents and unrealistic area frequencies. Forest types found in these areas are dominated by tree species more typically found in mixed-severity fire regimes (western larch, Douglas-fir, Engelmann Spruce, lodgepole pine, and subalpine fir).

In the Fir Mountain area we collected four usable fire-scar samples from which we discovered a series of fire years (1926, 1868, 1831, 1783, 1781, and 1757). Except for 1926, these fire years were also common to other parts of the Frosty Creek area. The deficiency of fire-scar data rendered an area frequency

impractical. Nevertheless, we did have two point-based MFFIs to sufficiently indicate pre-suppression frequency (Figure 10). The MFFI at these two points are 37 and 43.5 years, respectively. These individual points suggest a mean frequency of 40.2 years.

The 1926 fire covered a large portion of this area with varying effects, typical of a mixed-severity regime (Figure 10). A dense single layer of Douglas-fir, lodgepole pine, western larch, and Engelmann spruce indicate areas that burned severely in 1926. We found adjacent stands within this fire perimeter containing multiple cohorts that exhibited characteristics of a less severe ground-fire (Figure 11). The frequency discovered here is somewhat longer than most of the Frosty Creek planning area but is not unusual for a mixed-severity regime (Barrett et al. 1991, Agee 1994, Chappell and Agee 1996).

It is interesting to note that much of the stand-replacing portion of the 1926 fire is found along draw bottoms, intermittent streams, or depressions on the landscape (Figure 10). Exceptional growth potential present in these moist areas promote higher fuel levels and increase species diversity. We hypothesize that the combination of elevated fuel loading and development of some fire intolerant species may predispose these areas to variable stand replacing events.

We were not able to find any direct fire-scar evidence from the Cornell butte area. We were able however, to associate the 1910 fire found in Polygon 6 to the area through tree core analysis.

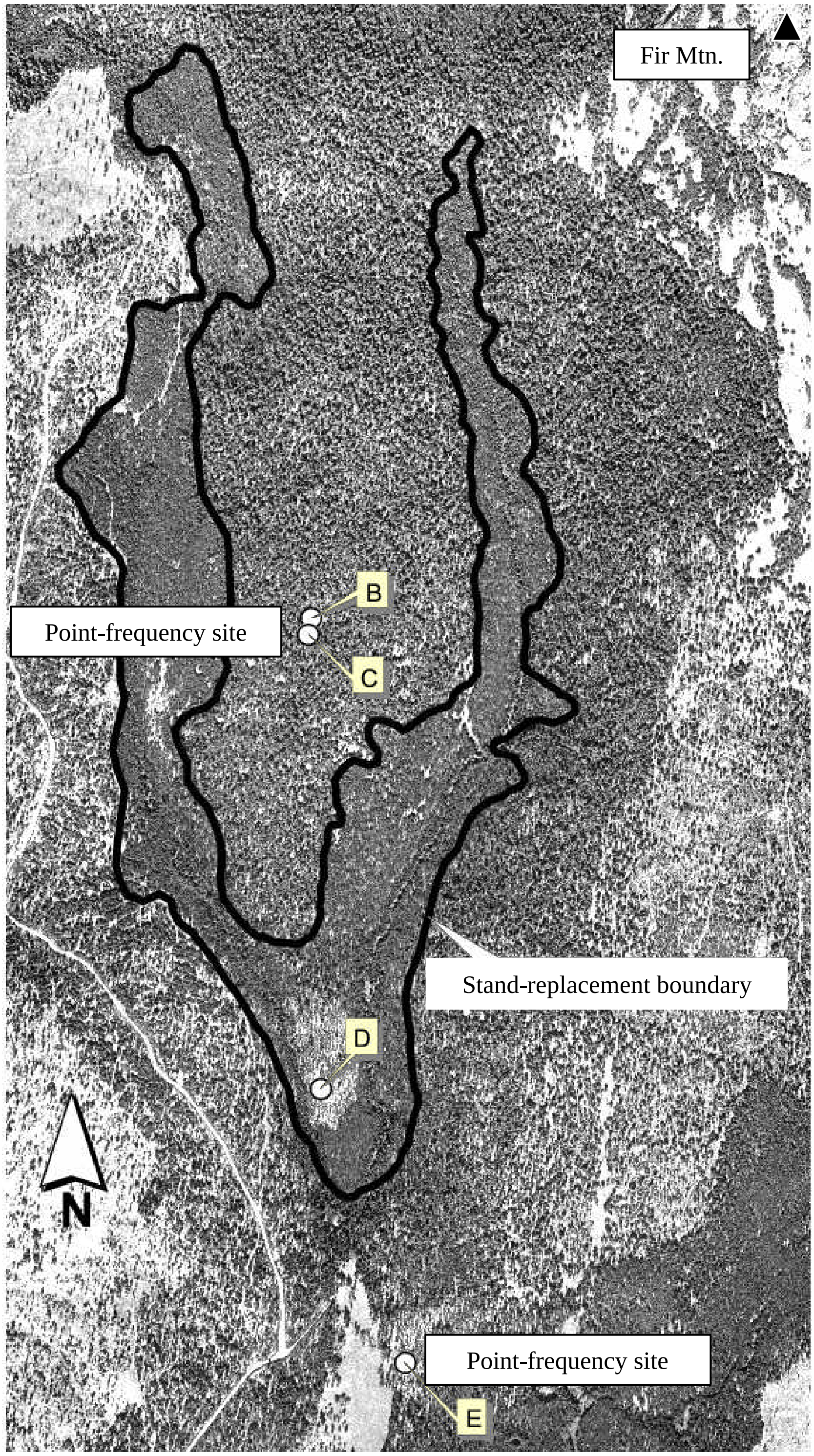

Figure 10. The region southwest of Fir Mountain has a mixed-severity fire regime, which means that whenever a fire occurred, portions of the forest were killed by crown fire while other portions burned on the ground allowing thicker-barked trees to survive. The dark-black line in the picture traces the boundary of a stand replacement burn that occurred in 1926 (note the single-layer, finely-textured forest). This same fire was an underburn at two point-frequency sites where at least three other ground fires occurred historically (Scar-samples B & C form one site [37-year MFFI], sample E the other [43.5-year MFFI]). Photo is from a 1998 digital orthophoto quadrangle.

Figure 11. The trees in the picture above developed under a mixed-severity fire regime southwest of Fir Mountain in the Frosty Creek planning area. The larger trees on the left were maintained under a low-severity fire regime whose multiple fires were documented on scar samples that included a fire in 1926. This 1926 fire burned at higher severity, killing the overstory where smaller trees on the right have since regenerated. This mixture of low-severity areas with high-severity areas distinguishes a mixed-severity fire regime.

5. SUMMARY

Results from this study indicate that the inherent fire regime for the Frosty Creek planning area (Polygons 1 through 8) was one of high frequency, low-severity fires. This low severity is demonstrated by the fact that the mean diameter of trees at stump height when first scarred was 4.1 inches with a range of 0.4 -17.0 inches and the abundance of fire-scared trees surviving multiple burns. This type of fire regime is also typical of the dry forest types in the ponderosa pine, Douglas-fir, and grand fir series along the eastern slopes of the Washington Cascade mountains (Everett, et. al. 2000).

Short fire frequencies suggest that this area was historically dominated by species more tolerant of fire such as ponderosa pine and western larch, since even low severity fires would kill trees that were more sensitive to fire. Douglas-fir would have been a component of early forests, but since it is quite intolerant of

fire when very young (Arno 1988, p. 133), would have been restricted to areas that burned somewhat less frequently or represented in discrete cohorts that established and persisted during one of the longer fire free intervals. Fire-free intervals greater than about 17 years could have allowed Douglas-fir to establish and grow tall enough to create a fuel ladder to the overstory. Subsequent fires might then have become stand replacing in those areas (sensu Everett et. al. 2000).

The mixed-severity area near Fir Mountain furnished little data for analysis although evidence from a limited number of samples suggests a point-based mean fire-frequency of 40.2 years. This area and the area northwest of Cornell Butte are considered cooler and more mesic, allowing for longer fire-free intervals with the last fire occurring in 1926 and 1910, respectively. Stands resulting from these fires are similar to those sampled on the Colville National Forest (Schellhaas et al. 2000a) and other mixed-severity fire regimes, especially on north-facing slopes (Everett et al. 2000, Agee 1994).

The overall topography within the Frosty Creek area is somewhat gentle and is lacking distinctive features such as sharp ridgelines and abrupt draw bottoms that may provide barriers to the spread of wildfire (Table 5). This topography may contribute to the uniform fire regime detected within Polygons 1 through 8.

The Frosty Creek area is currently out of synchrony with historical MFFIs by a factor of 14 in the high-frequency / low-severity areas (Polygons 1 through 8) and by a factor of 2 in the mixed-severity area near Fir Mountain. Currently, vegetation is connected horizontally and vertically across the landscape, predisposing this area for fires that are of greater severity than those that occurred during the past several centuries. The Cape Labelle fire that burned through a portion of the area during the summer of 2001 is an example of this type of high-severity fire.

6. MANAGEMENT IMPLICATIONS

This paper summarizes that the Frosty Creek area has diverged from historical conditions. The initial concern, therefore, is to return stand structure and species composition to sustainable conditions. Maintenance of historical disturbance patterns and processes should then become the emphasis, which would entail discontinuity in surface fuels or understory vegetation in low-severity areas and patchiness of overstory in mixed-severity areas.

Although statistical tests demonstrated significant differences between certain polygons, the biological implications may be negligible for management purposes. The pre-suppression polygon range of 4.7 to 11.4 WMFFI is entirely within the range of what is considered a frequent, low-severity fire regime (Agee 1999). Fire effects on forest structure would vary little between these upper and lower parameters except for the shrub layer. Longer intervals may allow this layer to advance further between successive fire events while shorter intervals would only maintain a grass component (Agee 1994, Agee 1999). Overstory stand structure would not deviate greatly within this range of frequency and would consist of a uniform mosaic of mature-tree clusters (Agee 1999).

Other areas display mixed-severity characteristics, exhibiting a fragmented overstory. However, this fragmentation in the overstory was not randomly distributed, similar to findings of Camp (1995) in the eastern Cascades. The higher severity (stand-replacement) burns seem to concentrate along draw bottoms, intermittent streams, or depressions on the landscape. A comparable example was documented by Agee (1998) in similarly forested regions of Idaho.

Data for these mixed-severity areas is somewhat limited but reveal opportunities for a different array of management options. Overstory patchiness was more apparent in the mixed-severity fire regime. The fragmentation in the overstory detected historically here implies periodic openings in canopy cover, which can have many ecological benefits. For example, openings are important for some species of wildlife and the successful establishment of western larch (Schmidt and Shearer 1992). It should be recognized however, that some areas likely experienced a gradient in lethality where single trees or small groups were left within a matrix of stand regeneration.

An aid for managing the low and mixed-severity areas can be found in the range of variability around WMFFI and MFFI intervals. It allows managers the flexibility needed to cope with the range of workforce, fiscal, or environmental concerns. The area range listed in Table 1 displays the actual maximum and minimum intervals recorded. A better tool would be the Weibull Exceedance Probability range, also found in Table 1, which only lists values within a certain significance level as related to the Weibull median, thus eliminating the statistically long and short intervals. This Weibull Exceedance Probability prioritizes the temporal distribution and allows the land manager to focus on the most significant portion of this range. For example, Polygon 4 has a range of actual fire-free intervals from 1 to 21 years whereas the Weibull Exceedance Probability range for this polygon is 2 to 7 years. This supports the conclusion that managing in 2 to 7 year intervals is more statistically valid than in 1 to 21 year intervals.

Fire extent maps in the appendix illustrate mosaic burn patterns created by differing ground-fuel conditions across the landscape and can be seen in the series of fire years including 1796, 1798, 1799 and 1800. The fire in 1800 did not overlap the area of the 1799 fire, demonstrating a reduced likelihood to re-burn areas recently burned. In addition, the 1794 fire acted as a fuel-break for the 1796 fire in the north end of the Frosty Creek planning area. This situation is

generally observed in low severity fire regimes within 3 to 4 years after fire, until grass and litter amounts are replenished. Agee (1999) also reports these natural barriers at less than three years. Similar mosaic burn patterns also occurred in the (1772, 1774, 1776, 1778) and (1717, 1719, 1720, 1721) series.

Use of means, medians, and ranges of historical fire-frequency and size could be used as a guide for management within the Frosty Creek planning area. These historical disturbance patterns can help design a spatial and temporal mosaic pattern of treatments and patch sizes across the planning area to help fragment fuel continuity and ensure the sustainability of these forests.

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APPENDIX

Table 2. Point-based estimates of fire frequency for 88 points in the Frosty Creek area (1683-1917).

Point	WMFFI	SD	Min FI	Max FI	Point	WMFFI	SD	Min FI	Max FI
101	14.11	4.85	7	26	415	14.47	8.76	4	29
102	13.49	5.54	3	26	501	17.08	8.92	4	33
103	12.71	6.46	2	26	502	16.37	7.39	6	28
104	14.48	5.71	6	27	503	18.50	9.96	2	36
105	17.82	6.77	10	27	504	14.20	9.16	2	36
106	12.10	6.28	3	27	505	18.70	9.34	2	36
107	8.86	5.04	2	21	506	13.66	6.08	5	24
108	15.23	4.3	9	26	507	18.73	7.44	12	36
109	9.78	6.82	2	26	601	17.11	5.07	12	28
110	14.27	4.41	9	24	602	14.57	6.5	6	28
111	10.97	4.82	4	18	603	16.72	7.7	7	34
112	16.46	3.4	9	21	604	18.54	5.94	13	30
113	11.77	5.08	5	17	605	18.69	5.05	13	28
114	15.75	4.07	8	20	606	17.11	5.07	12	28
115	15.25	3.96	9	22	607	19.73	9.2	12	42
116	14.65	7.75	3	28	608	15.65	6.52	4	28
201	9.48	7.99	2	31	609	19.14	5.5	13	28
202	13.29	7.59	7	36	610	18.84	7.06	12	34
203	9.32	4.95	3	20	611	15.64	5.63	7	28
204	11.37	5.17	4	21	701	15.92	4.81	8	27
205	9.66	6.17	3	20	702	14.50	6.83	7	31
206	13.27	6.64	3	25	703	13.73	7.55	3	30
207	10.63	5.4	3	22	704	11.93	6.58	3	27
208	8.95	5.28	4	25	705	11.68	4.5	3	17
209	8.84	2.89	4	14	706	11.61	4.83	4	19
210	11.78	6.64	5	26	707	11.75	5.55	6	23
301	14.47	8.96	3	31	708	12.49	5.41	5	27
302	16.48	6.92	8	31	709	19.19	11.37	8	40
303	13.53	8.37	3	31	710	8.63	3.47	4	16
304	16.84	6.09	10	28	711	11.91	5.6	4	25
401	9.54	6.79	2	25	712	9.71	6.33	4	26
402	13.54	6.18	3	27	713	10.31	6.39	4	31
403	18.44	8.57	4	35	714	9.35	4.59	4	19
404	11.84	6.87	4	28	715	12.87	10.71	5	47
405	16.41	7.87	6	30	716	15.66	6.87	5	27
406	15.82	7.76	6	27	801	15.73	6.37	8	27
407	14.60	6.55	7	28	802	9.51	4.09	3	18
408	10.55	6.31	3	25	803	10.06	4.54	4	20
409	12.20	7.11	2	28	804	9.16	6.88	4	32
410	12.26	7.51	4	27	805	11.81	4.98	5	23
411	10.18	4.65	2	18	806	11.99	4.7	4	20
412	9.45	5.81	3	24	807	14.39	5.25	7	25
413	14.18	8.84	4	35	808	16.34	7.73	7	27
414	18.41	7.26	7	31	809	12.31	8.66	4	35

Table 4. Acres burned by year and polygon.

Fire year	Polygon 1	Polygon 2	Polygon 3	Polygon 4	Polygon 5	Polygon 6	Polygon 7	Polygon 8	Total
2001	90								90
1941		67							67
1917	277	258	193	28					756
1910	576					672	1026	140	2414
1909	89								89
1906								355	355
1904	26	501			84				611
1896			55	1021		1024	604	94	2798
1894	952								952
1893			23						23
1891							44		44
1889								31	31
1886	217	652	160	218			66	9	1322
1883	1473	875					1132	752	4232
1882		194		59					253
1878				49					49
1871	390			50			379	378	1197
1868	685	619	251	1051	672	978	654		4910
1866	716	302		1128			431	657	3234
1863	211	889		61					1161
1857	1979	613							2598
1854		342	232	996	156	1175	1368	755	5024
1851				359					359
1848							21		21
1844	1717	842							2559
1842					117				117
1841								48	48
1839	132	31	128	159			1119	580	2149
1835	9						34	37	80
1834		206		51					257
1831	719	569	264	943	725	1180	1376	758	6534
1829	575								575
1827	1194	1098	303	1478			676	496	5245
1822	293	383					478	548	1702
1816		36							36
1812	1704	860	273	1512	746	1180	1376	758	8412
1808				20					20
1804	178	1015	291	124			750	753	3111
1800			20	1289	394	131			1834
1799						1018	542		1560
1798		204							204
1796	505						394	310	1209

Fire year	Polygon 1	Polygon 2	Polygon 3	Polygon 4	Polygon 5	Polygon 6	Polygon 7	Polygon 8	Total
1794	591	1258	92	205					2146
1791		11	36	58	31				136
1783	784	1038	259		123				2204
1781		45		1101	682	1178	1371	755	5132
1778			66	116					182
1776	268	664							932
1774	272								272
1772					35				35
1771	247	224		682					1153
1769							23	442	465
1768		1368	285	132					1785
1765			134	1304	359	1177	614	138	3726
1758						28	1261	745	2034
1757	2104	1098			538				3740
1756			260	215					475
1751			57	931	238	958	1368	755	4307
1748		98		94					192
1739	1358	1292	48	1279	752	1056	866	548	7199
1733		20	66	33					119
1732				25	33	67			125
1731	945	1034					1259	754	3992
1730				406					406
1729		20	95	158					273
1725		20		145					165
1721						237			237
1720				778					778
1719							42		42
1717	590	763		25					1378
1714				674	753	653	1372	755	4207
1712	569			186					755
1708				360	317	276	165		1118
1706						48			48
1705	1277	1123	257	238					2895
1695	476			46					522
1694		319		24			70		413
1689					190		24	32	246
1687		218		662	423	918	1349	296	3866
1683	1173	802	289	92					2356
Total	**2236**	**1760**	**549**	**1723**	**761**	**1180**	**1376**	**760**	**10345**

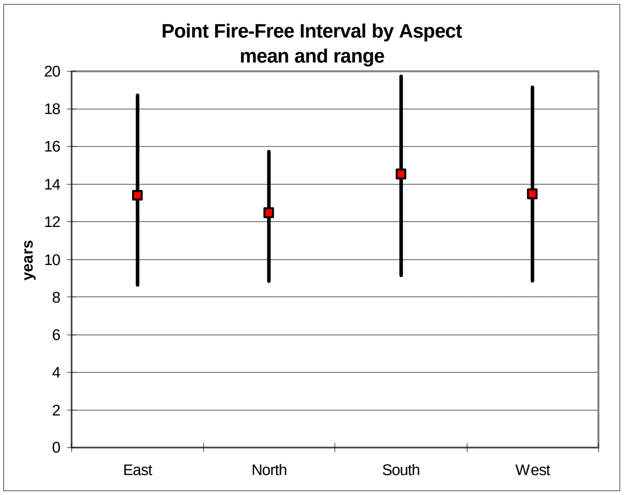
Table 4. Acres burned by year and polygon (continued).

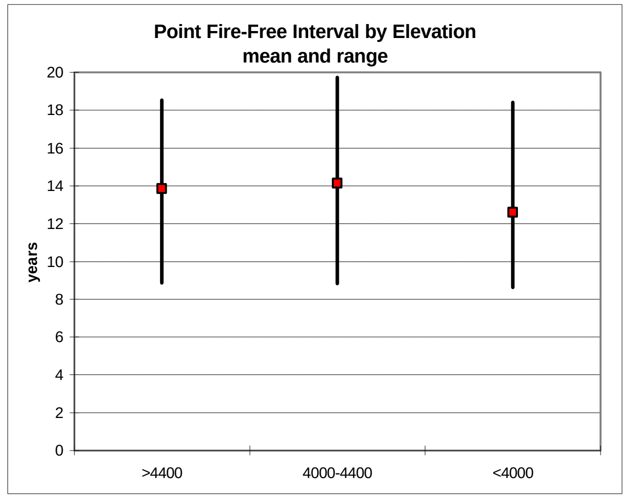
Point fire-free interval by aspect
1683-1917

Aspect	minimum	maximum	mean	SD	C of V	n
East	8.63	18.73	13.41	3.9	0.29	11
North	8.84	15.73	12.47	2.54	0.2	5
South	9.16	19.73	14.53	3.29	0.23	27
West	8.86	19.14	13.48	2.77	0.21	45

Point fire-free interval by elevation
1683-1917

Elevation	minimum	maximum	mean	SD	C of V	n
>4400	8.86	18.54	13.84	2.93	0.21	24
4000-4400	8.84	19.73	14.13	3.17	0.22	46
<4000	8.63	18.41	12.6	2.92	0.23	18



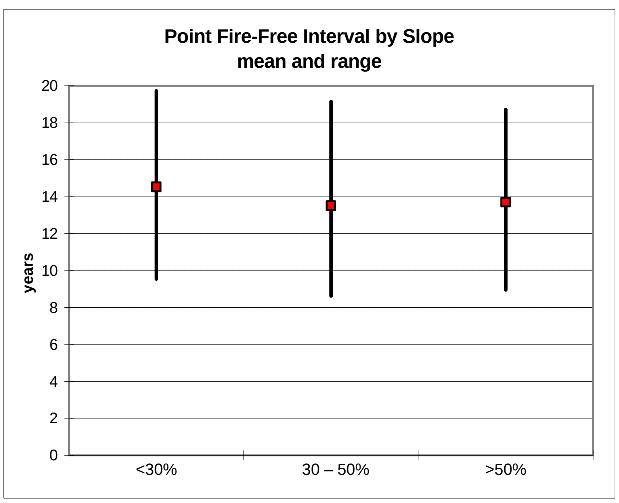


Point fire-free interval by slope
1683-1917

Slope	minimum	maximum	mean	SD	C of V	n
< 30%	9.54	19.73	14.53	2.87	0.2	15
30-50%	8.63	19.14	13.51	3.18	0.24	48
> 50%	8.95	18.73	13.7	3.06	0.22	25

Point fire-free interval by topographic position
1683-1917

Topo.	minimum	maximum	mean	SD	C of V	n
Lower 3rd	8.63	19.19	13.92	3.37	0.24	22
Middle 3rd	8.84	19.14	13.59	3.12	0.23	37
Upper 3rd	9.45	18.84	14.09	3.07	0.22	21
Ridgetop	9.51	17.08	12.98	2.42	0.19	8



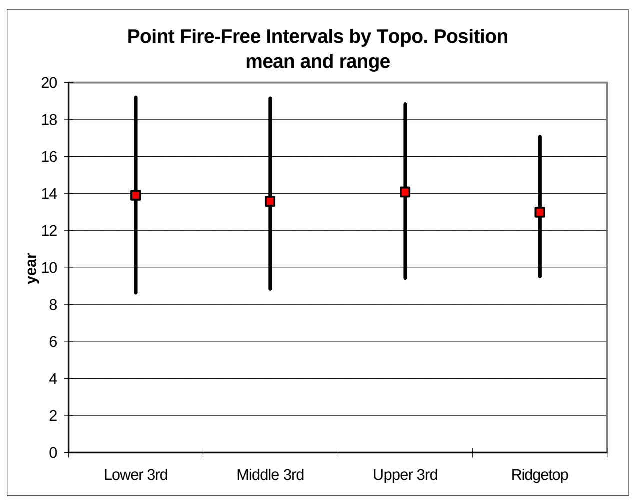
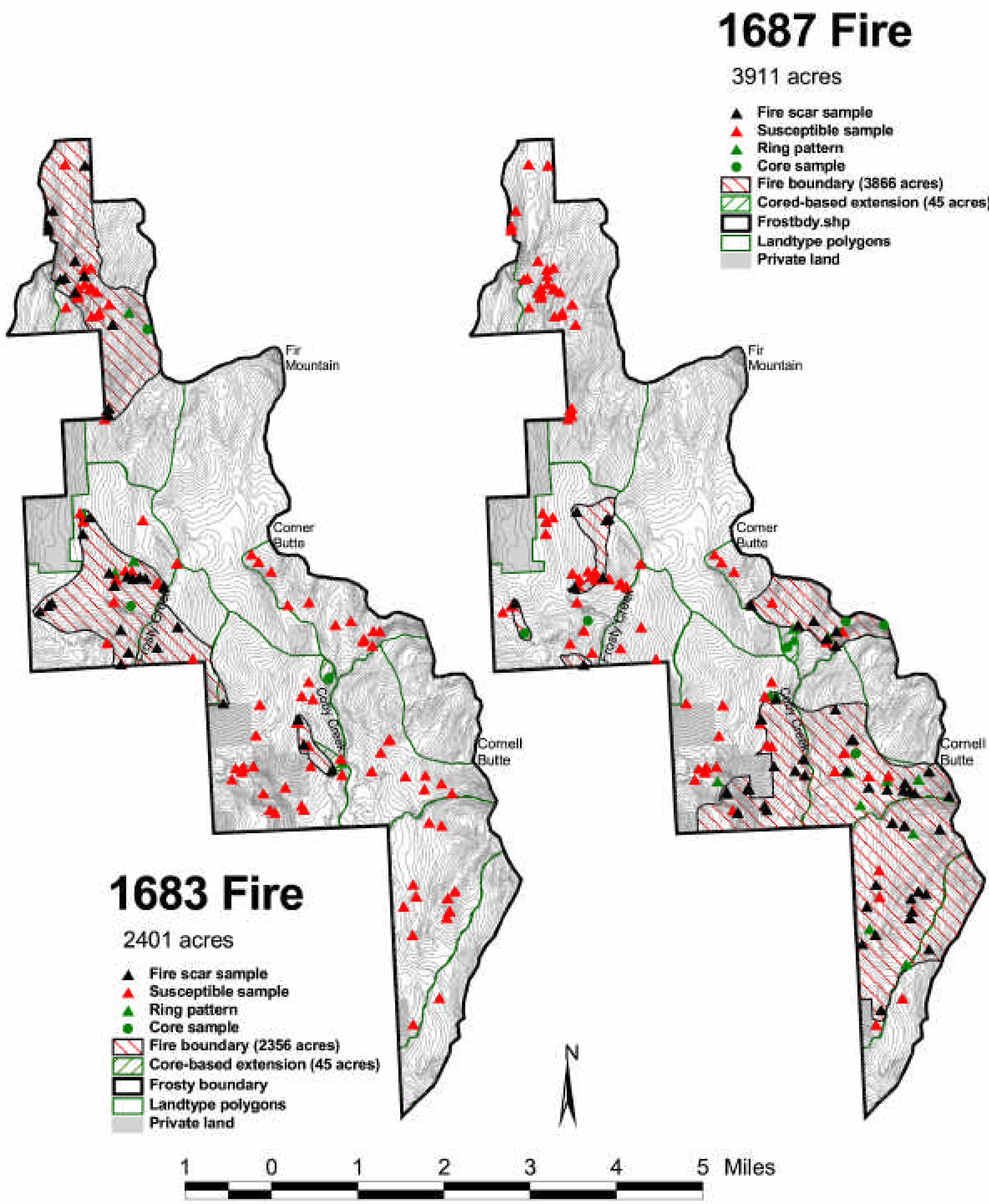
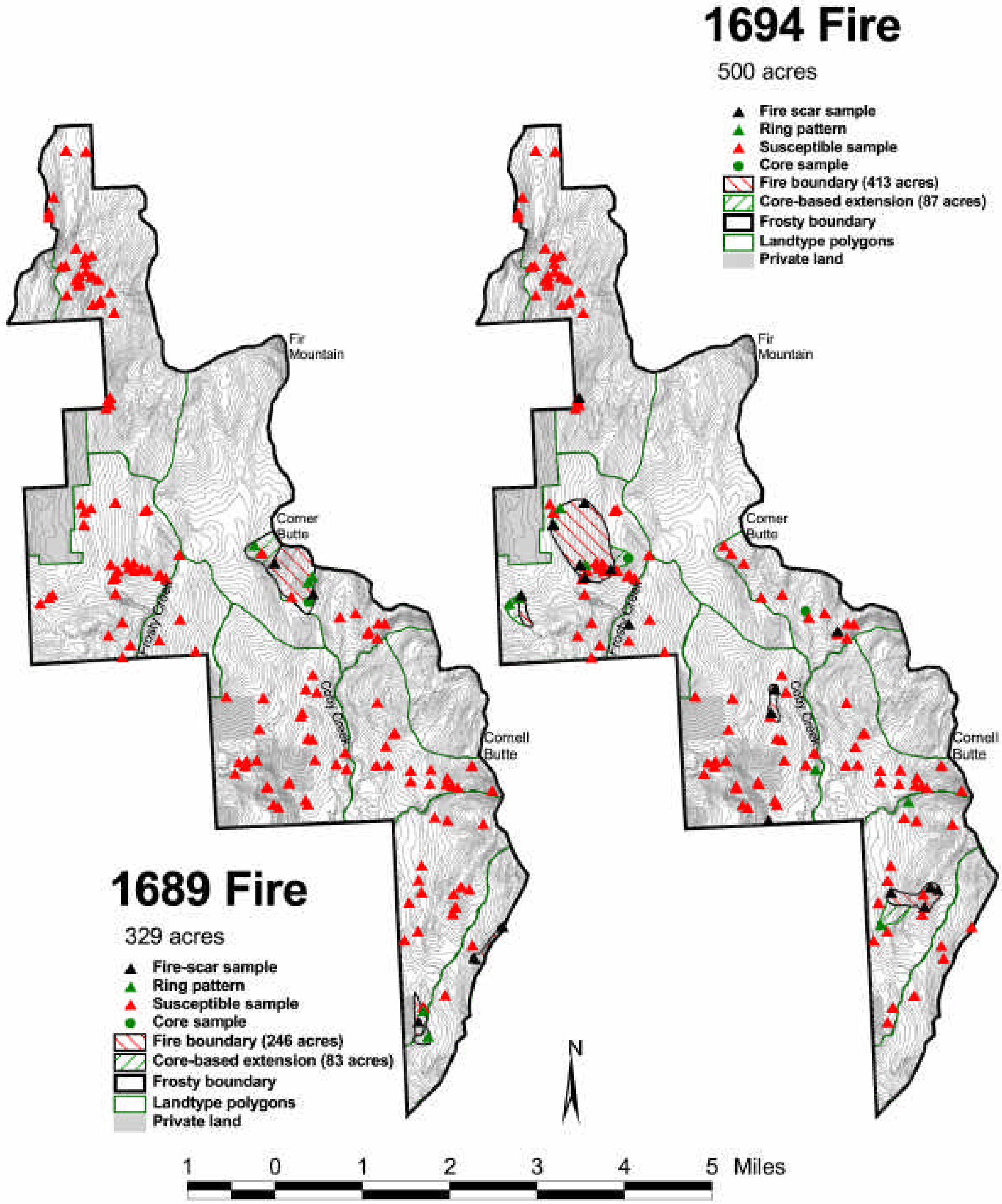
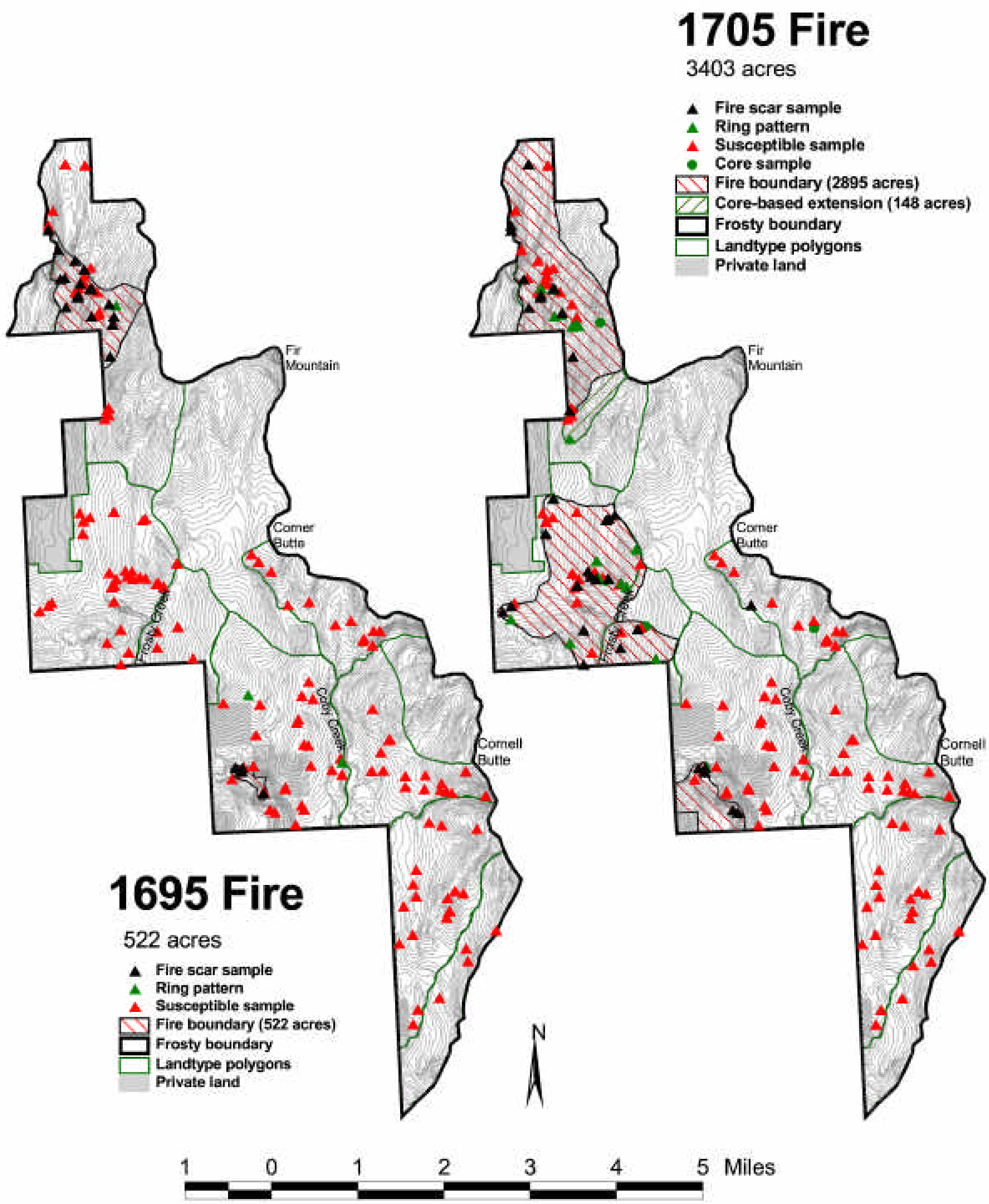
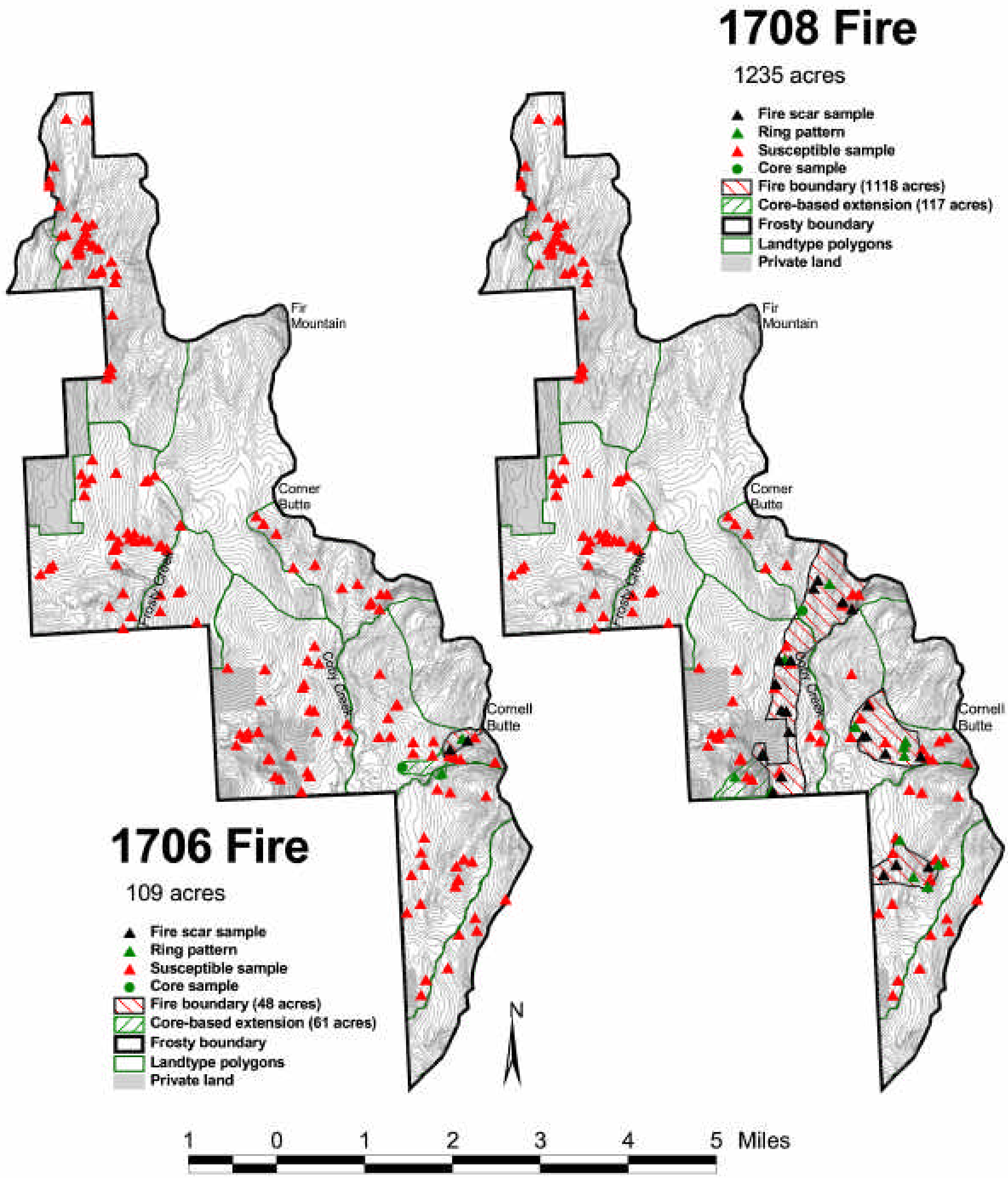


Figure 8. Summary of point Weibull median FFI by aspect, elevation, slope, and topographic class.

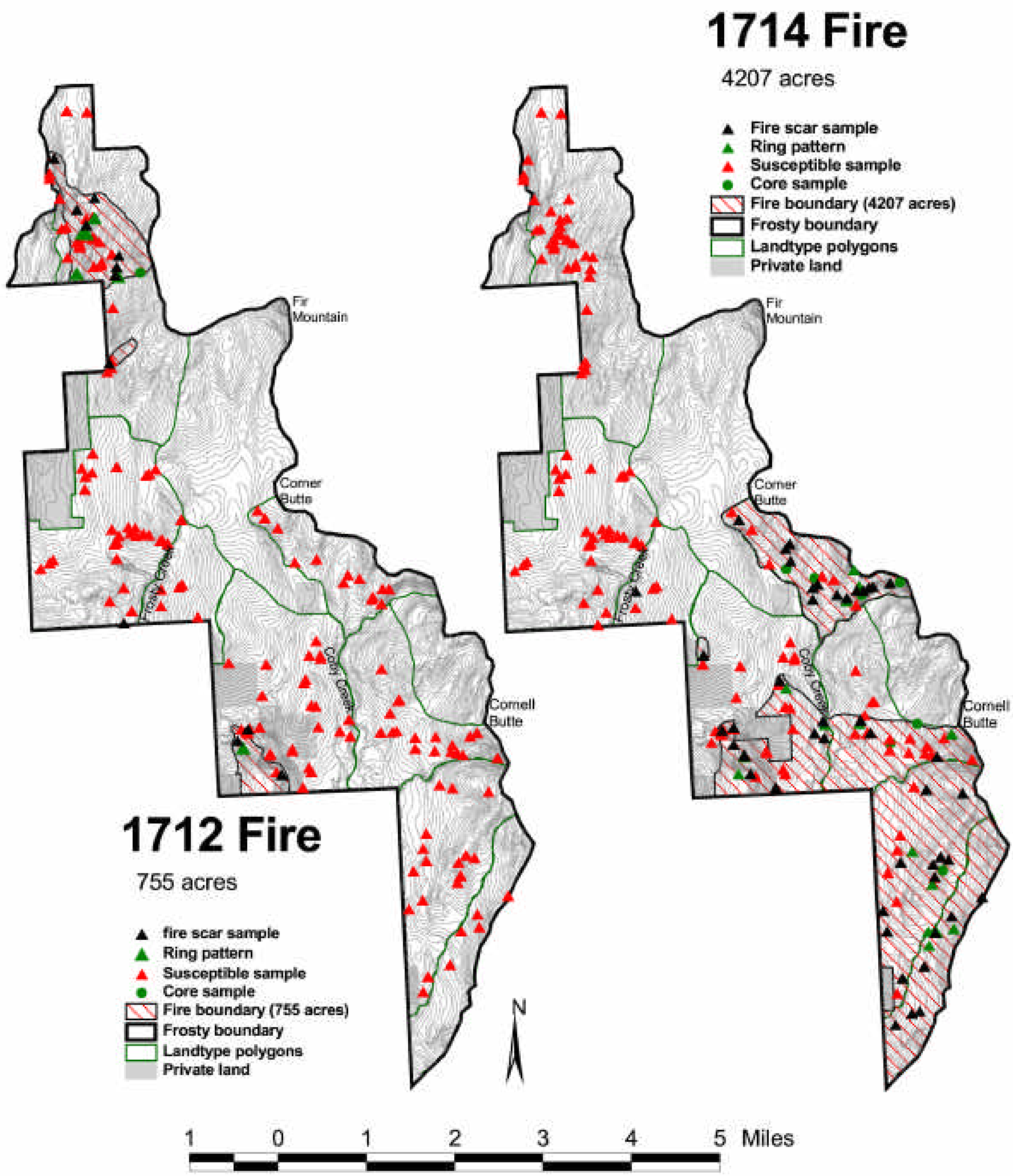

1687 Fire
3911 acres
Fire scar sample
Susceptible sample
Ring pattern
Core sample
Fire boundary (3866 acres)
Cored-based extension (45 acres)
Frostbdy.shp
Landtype polygons
Private land
Fir Mountain
Comer Butte
Cornell Butte
Frosty Creek
Cold Creek
1683 Fire
2401 acres
Fire scar sample
Susceptible sample
Ring pattern
Core sample
Fire boundary (2356 acres)
Core-based extension (45 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

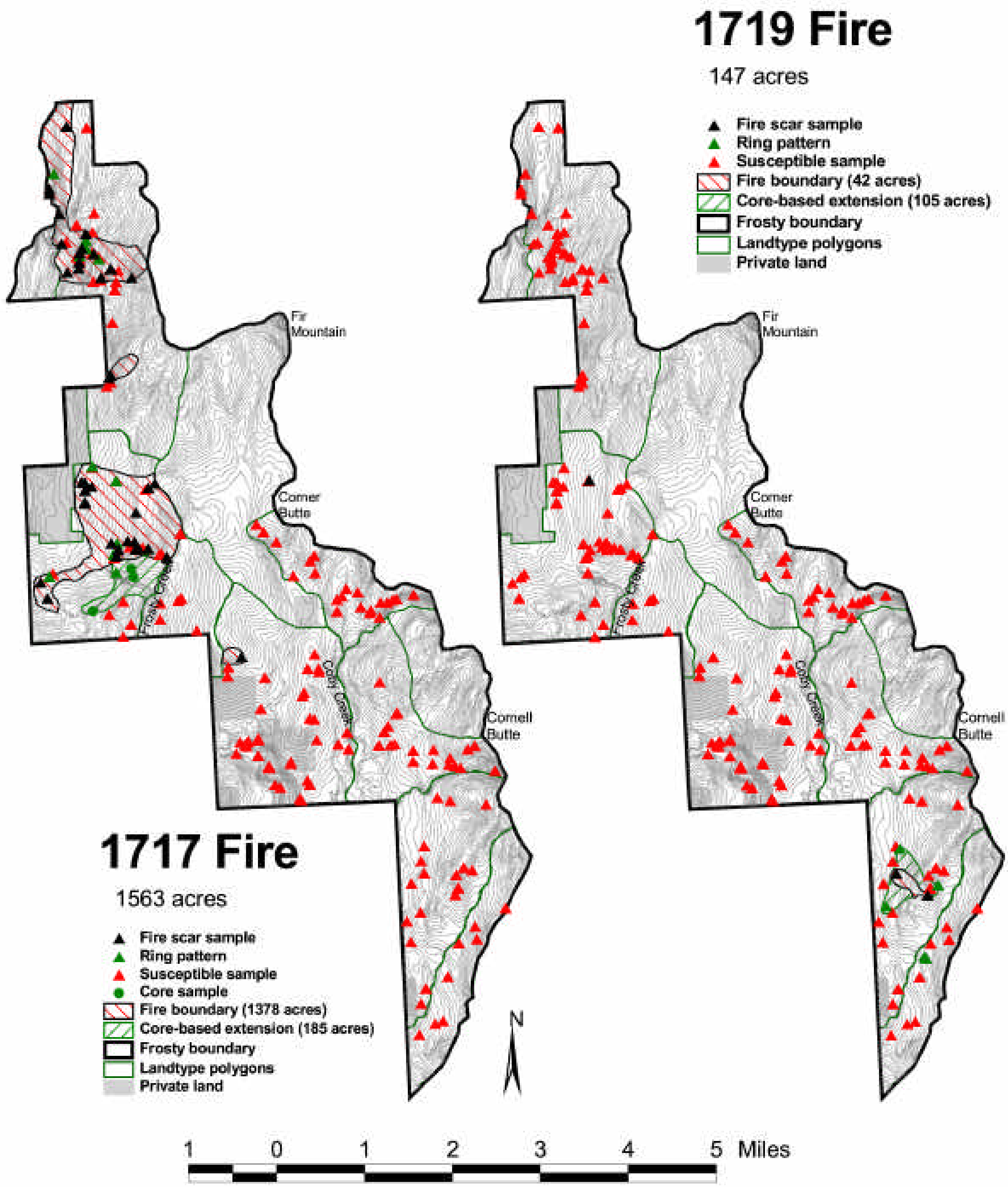

1694 Fire
500 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (413 acres)
Core-based extension (87 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Frosty Creek
Colby Creek
Cornell Butte
1689 Fire
329 acres
Fire-scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (246 acres)
Core-based extension (83 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

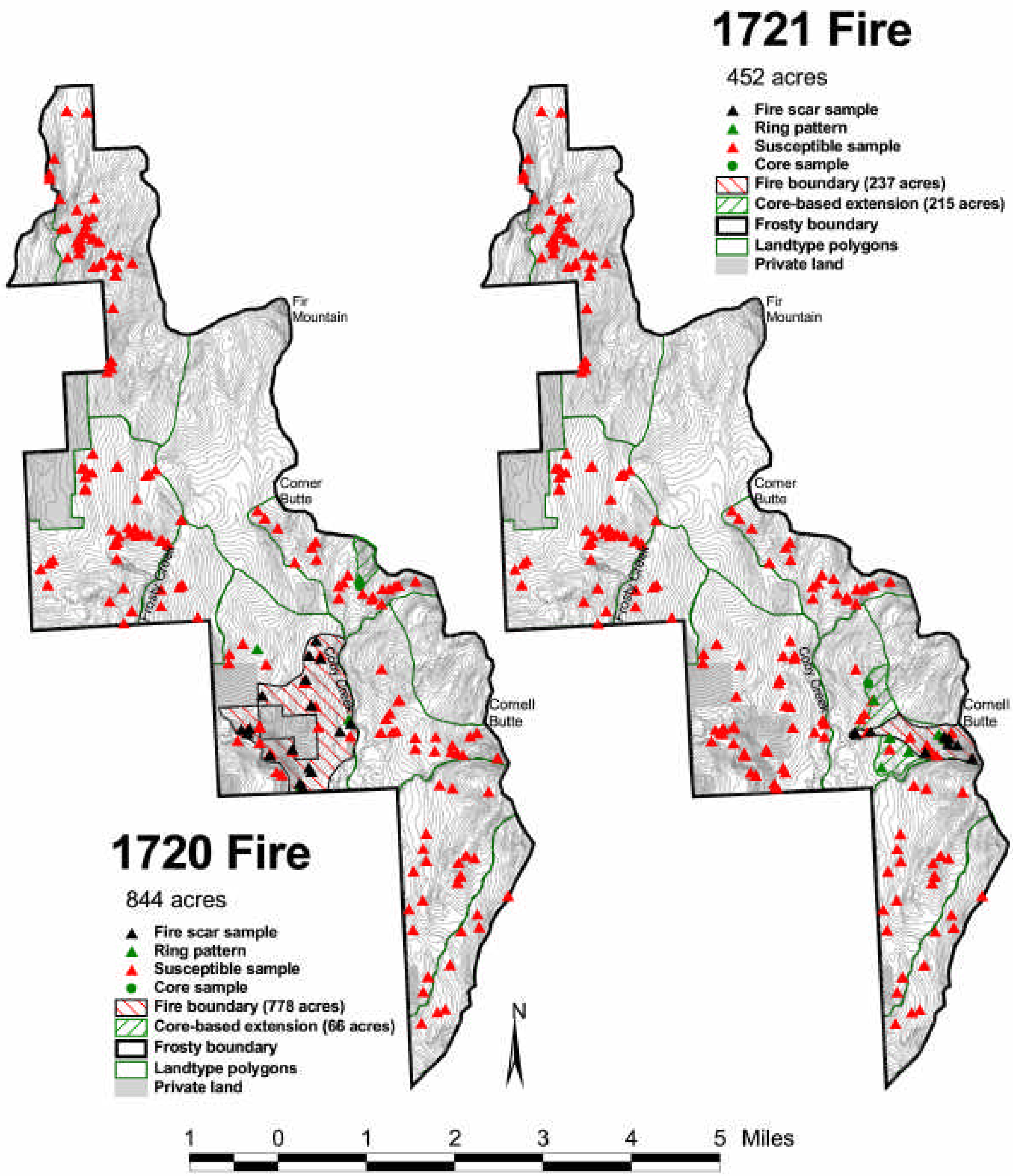

1705 Fire
3403 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2895 acres)
Core-based extension (148 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Crosby Creek
Frosty Creek
1695 Fire
522 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (522 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

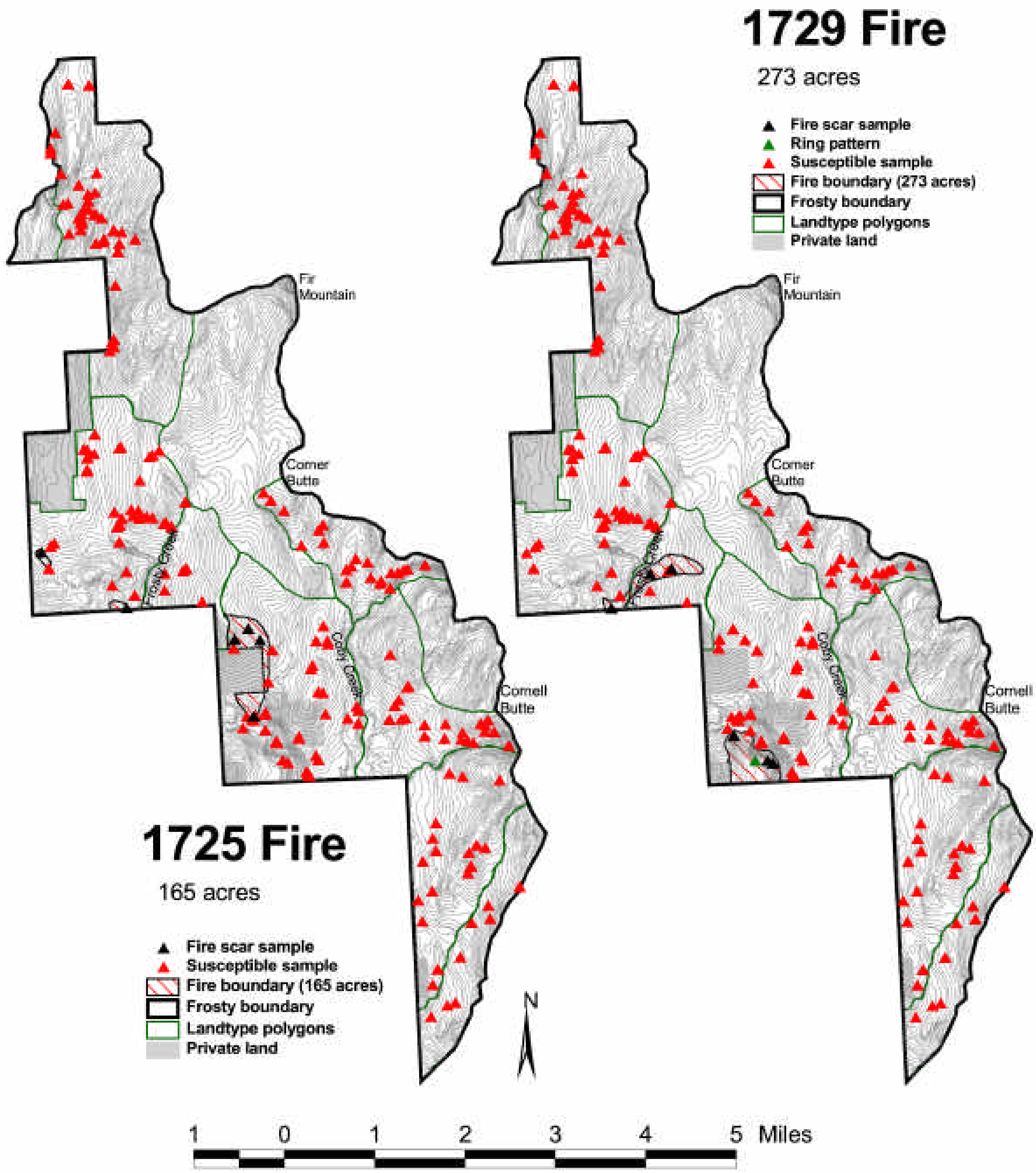


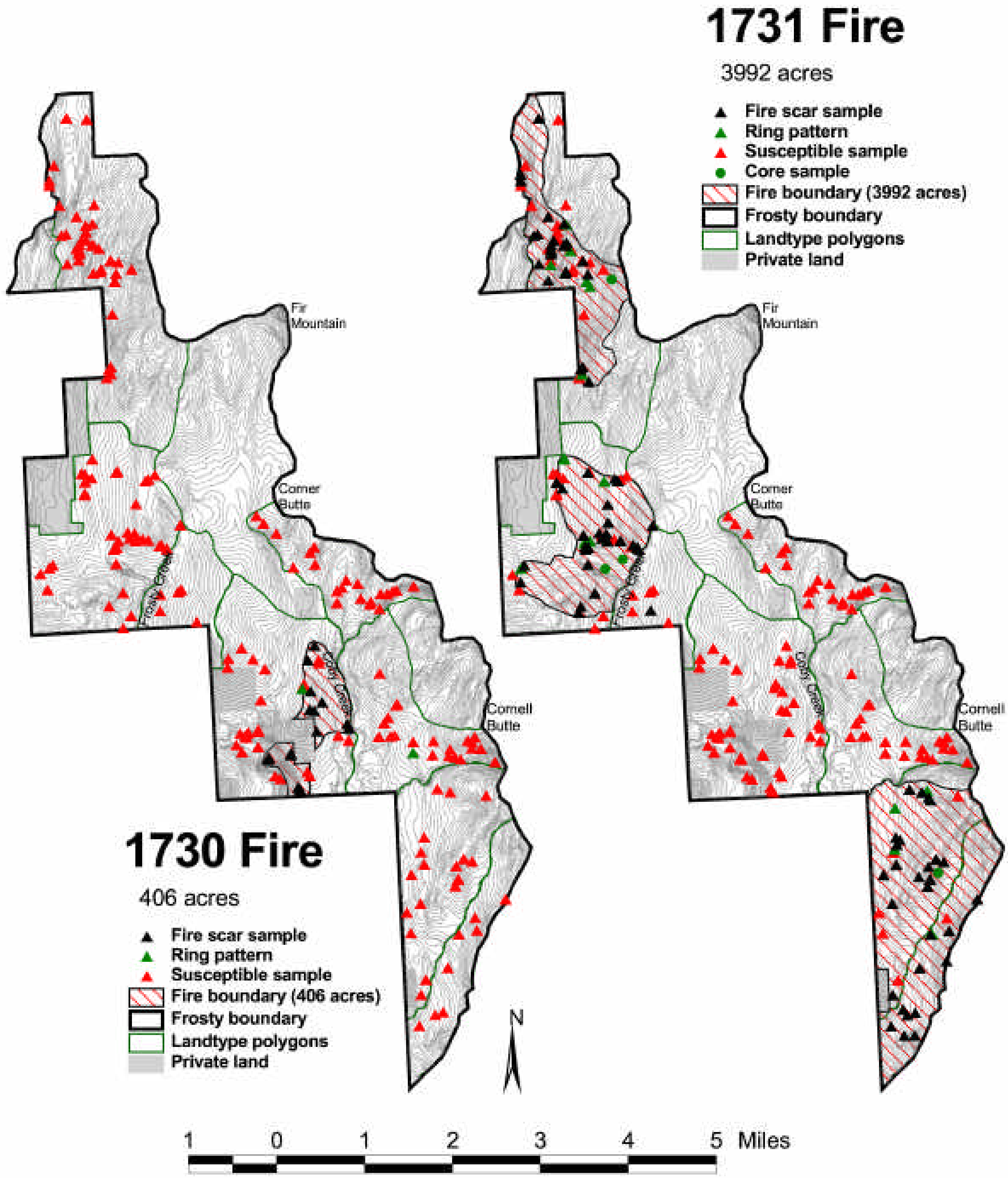
1708 Fire
1235 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1118 acres)
Core-based extension (117 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Frosty Creek
Cody Creek
Cornell Butte
1706 Fire
109 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (48 acres)
Core-based extension (61 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

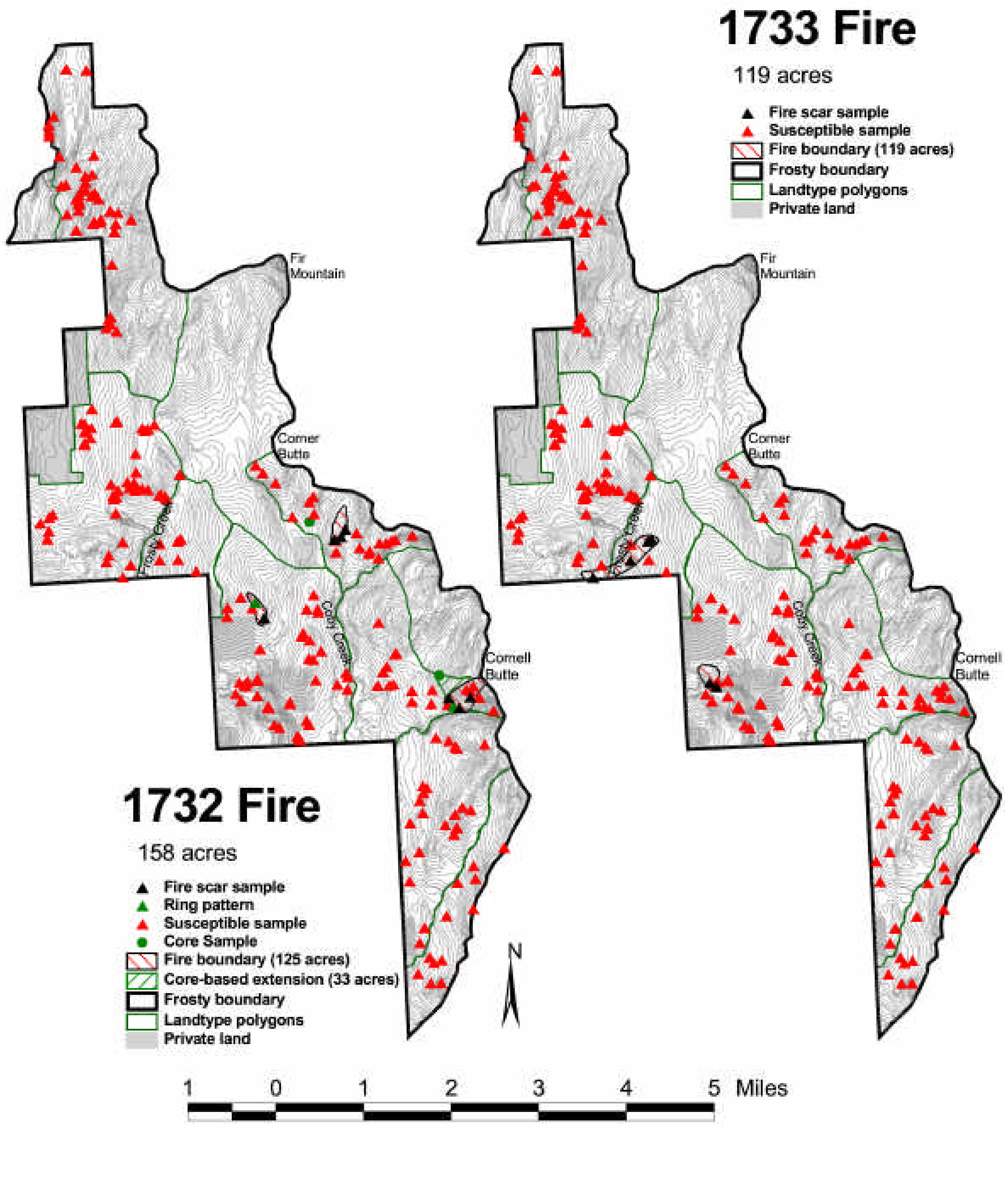

1714 Fire
4207 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (4207 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cody Creek
1712 Fire
755 acres
fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (755 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

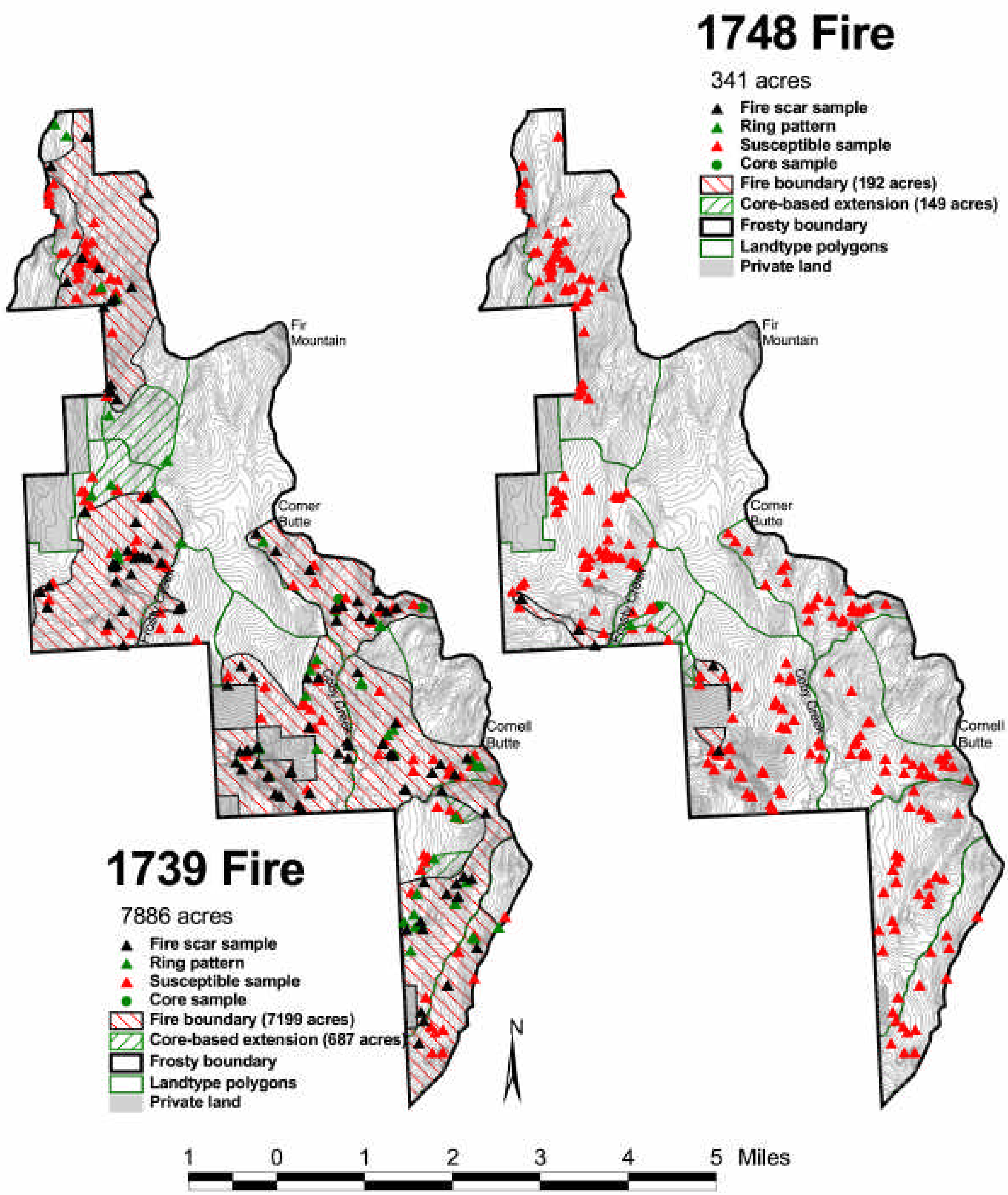

1719 Fire
147 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (42 acres)
Core-based extension (105 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Frosty Creek
Colby Creek
Cornell Butte
1717 Fire
1563 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1378 acres)
Core-based extension (185 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

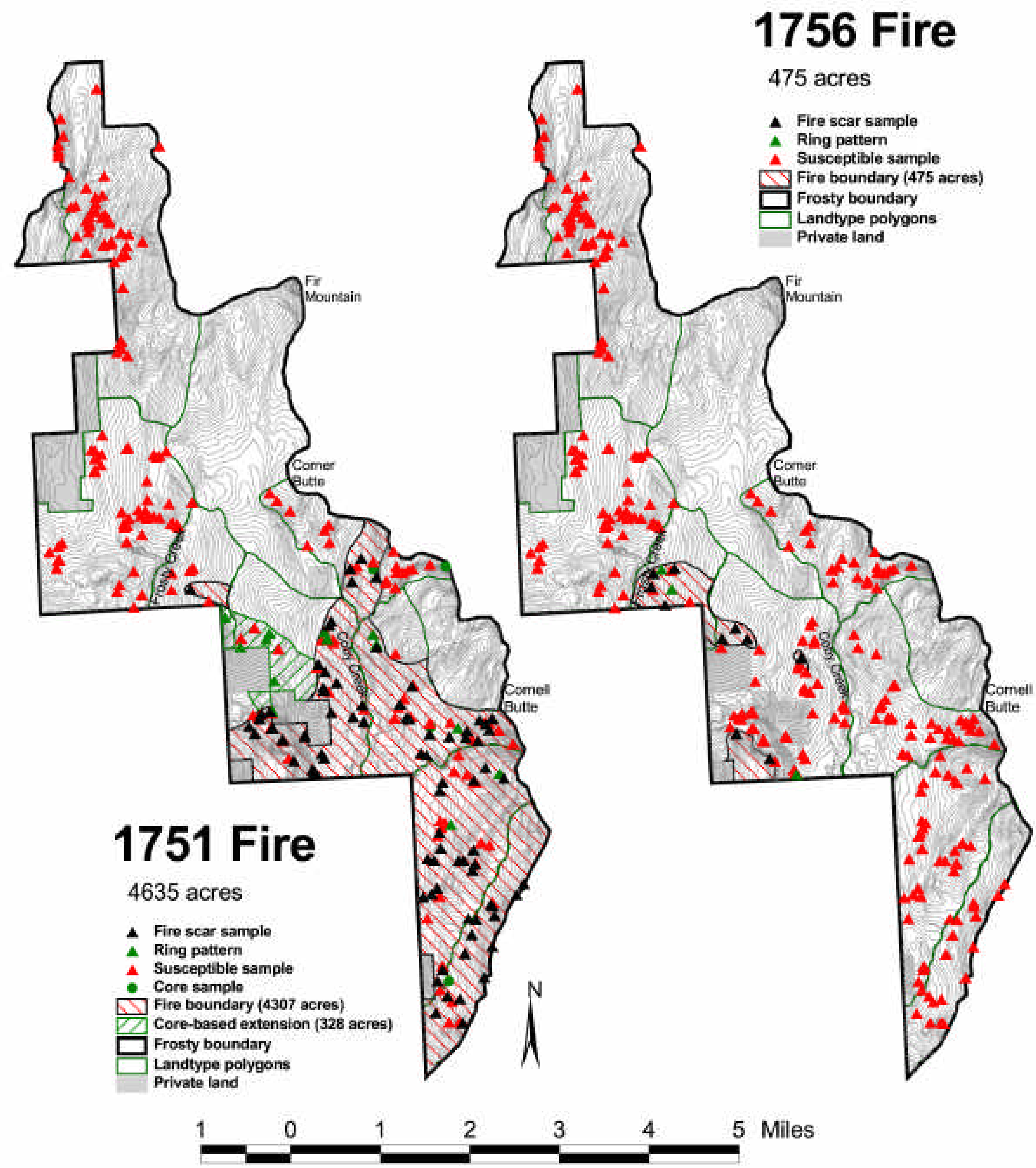

1721 Fire
452 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (237 acres)
Core-based extension (215 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Frosty Creek
Coby Creek
Cornell Butte
1720 Fire
844 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (778 acres)
Core-based extension (66 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

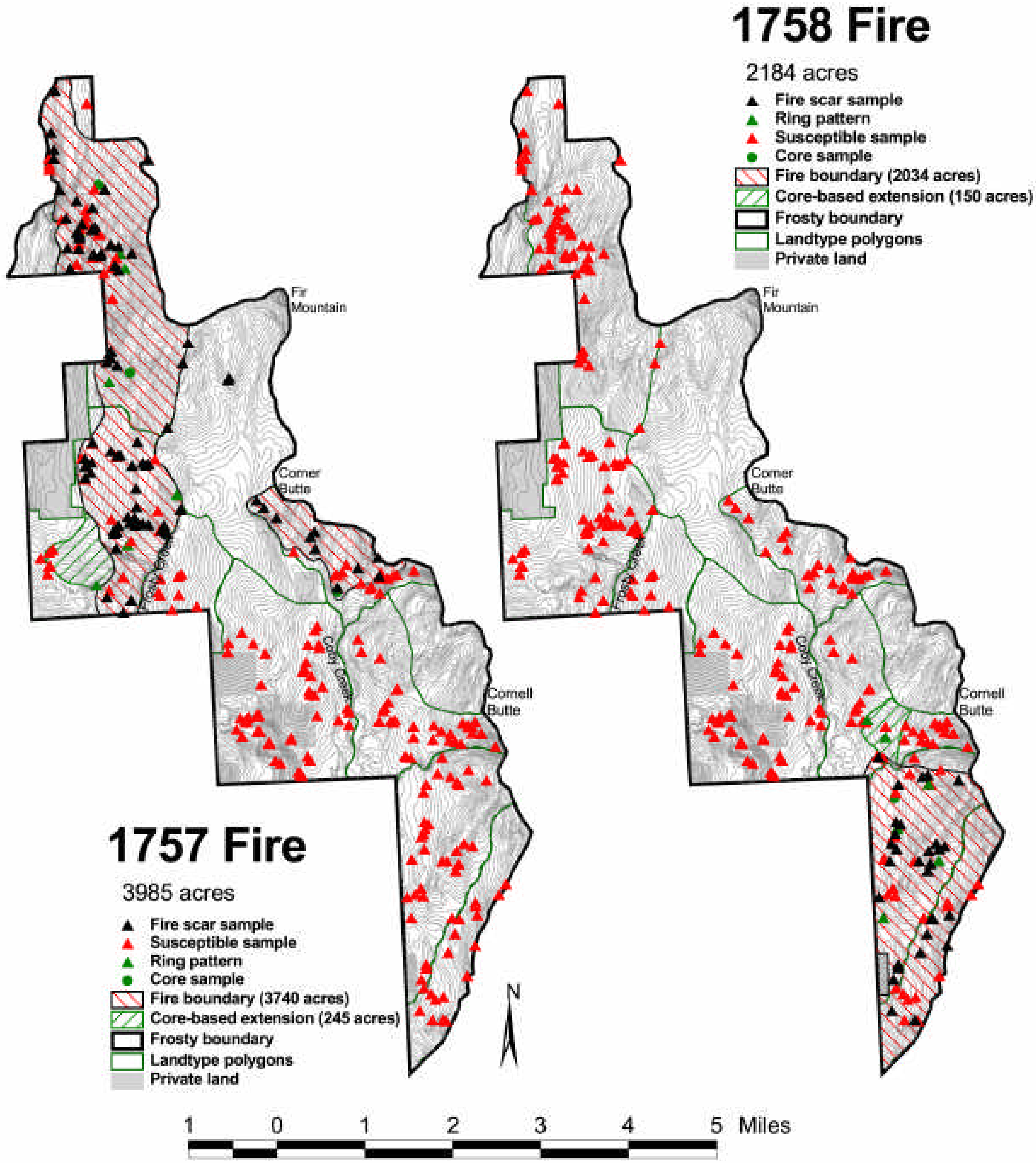

1729 Fire
273 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (273 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cobb Creek
1725 Fire
165 acres
Fire scar sample
Susceptible sample
Fire boundary (165 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

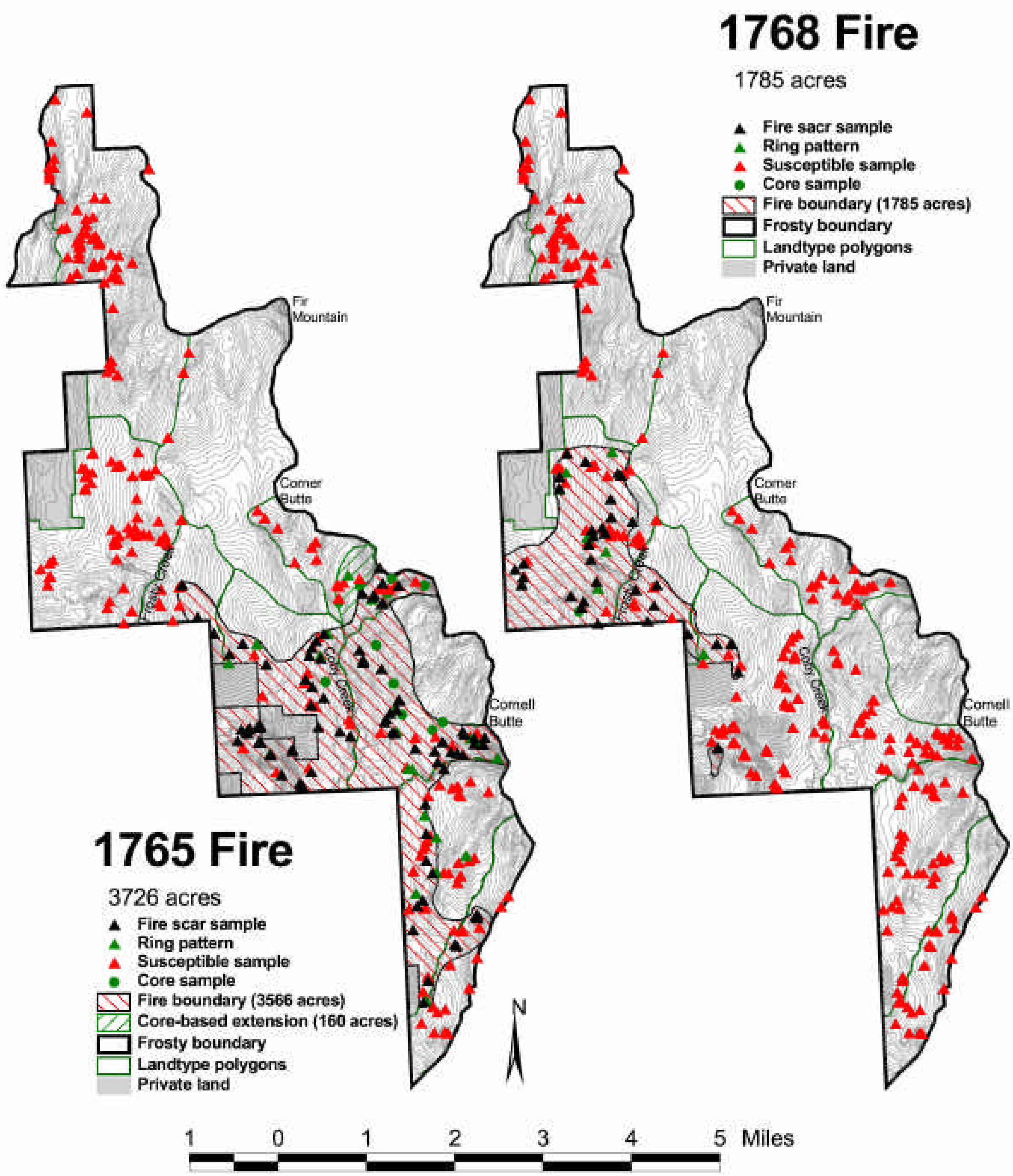

1731 Fire
3992 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (3992 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cobb Creek
1730 Fire
406 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (406 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

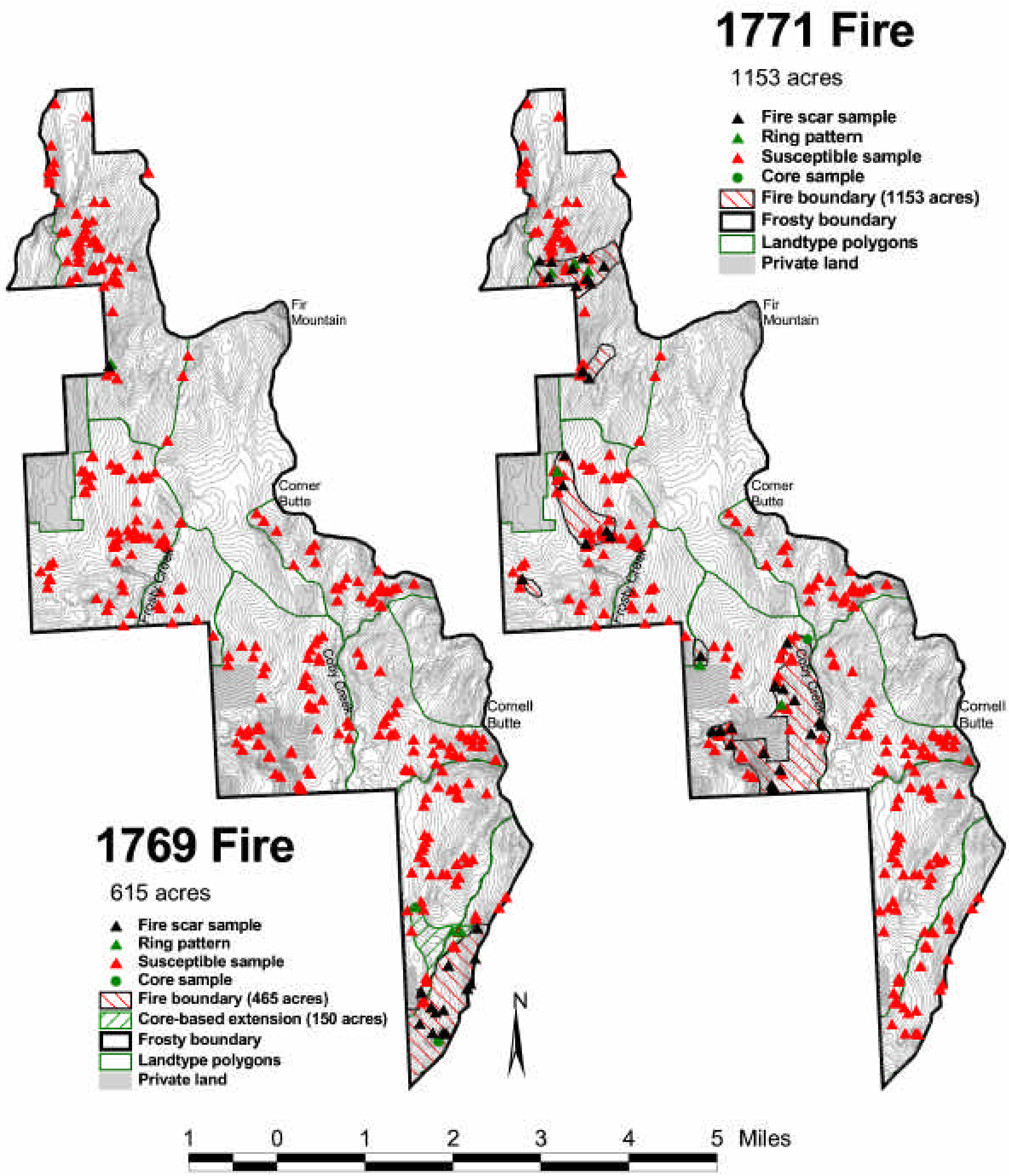

1733 Fire
119 acres
Fire scar sample
Susceptible sample
Fire boundary (119 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cosby Creek
1732 Fire
158 acres
Fire scar sample
Ring pattern
Susceptible sample
Core Sample
Fire boundary (125 acres)
Core-based extension (33 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

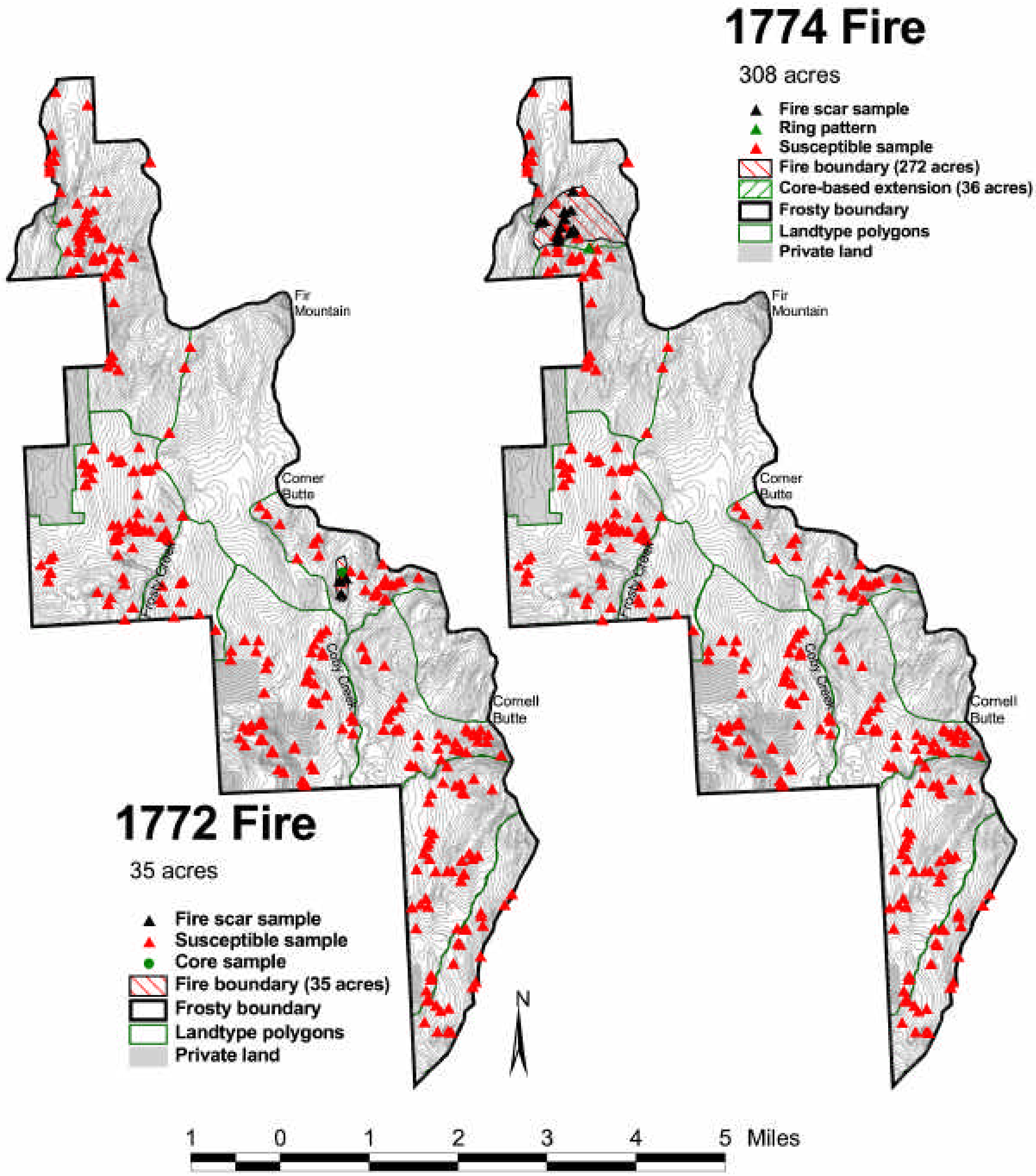

1748 Fire
341 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (192 acres)
Core-based extension (149 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1739 Fire
7886 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (7199 acres)
Core-based extension (687 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

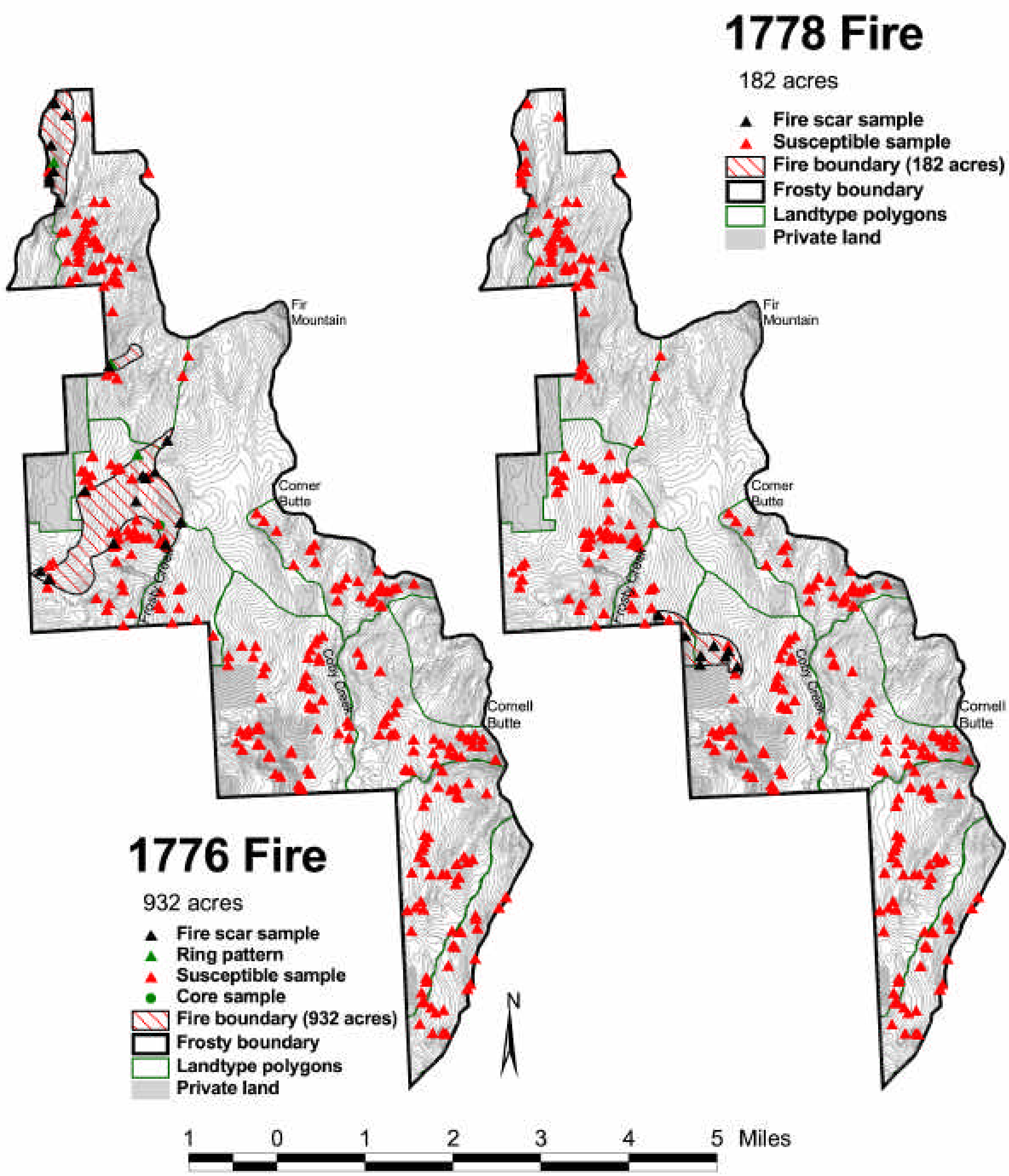

1756 Fire
475 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (475 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
Frosty Creek
1751 Fire
4635 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (4307 acres)
Core-based extension (328 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

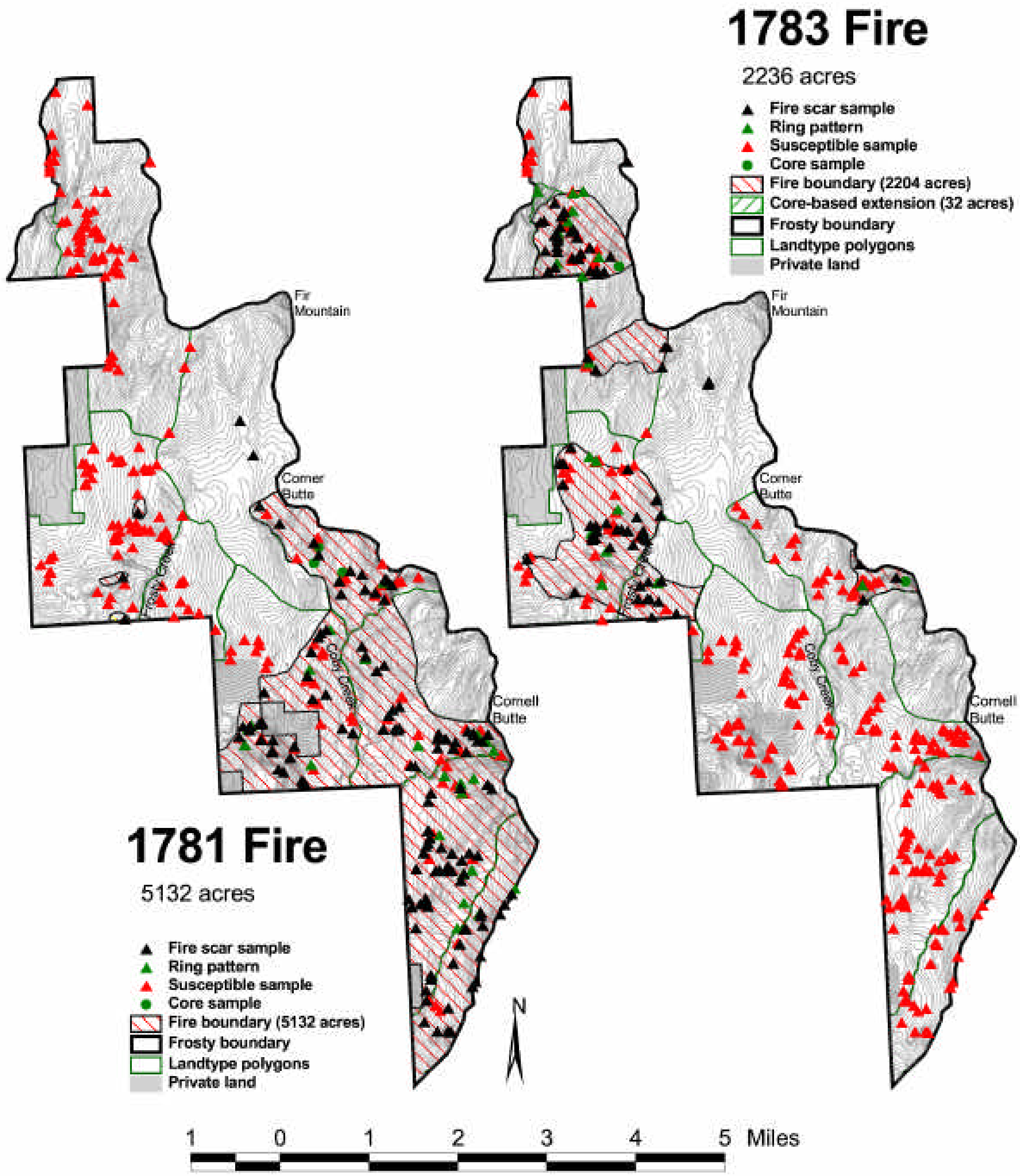

1758 Fire
2184 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2034 acres)
Core-based extension (150 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coby Creek
1757 Fire
3985 acres
Fire scar sample
Susceptible sample
Ring pattern
Core sample
Fire boundary (3740 acres)
Core-based extension (245 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1768 Fire
1785 acres
Fire sacr sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1785 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1765 Fire
3726 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (3566 acres)
Core-based extension (160 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

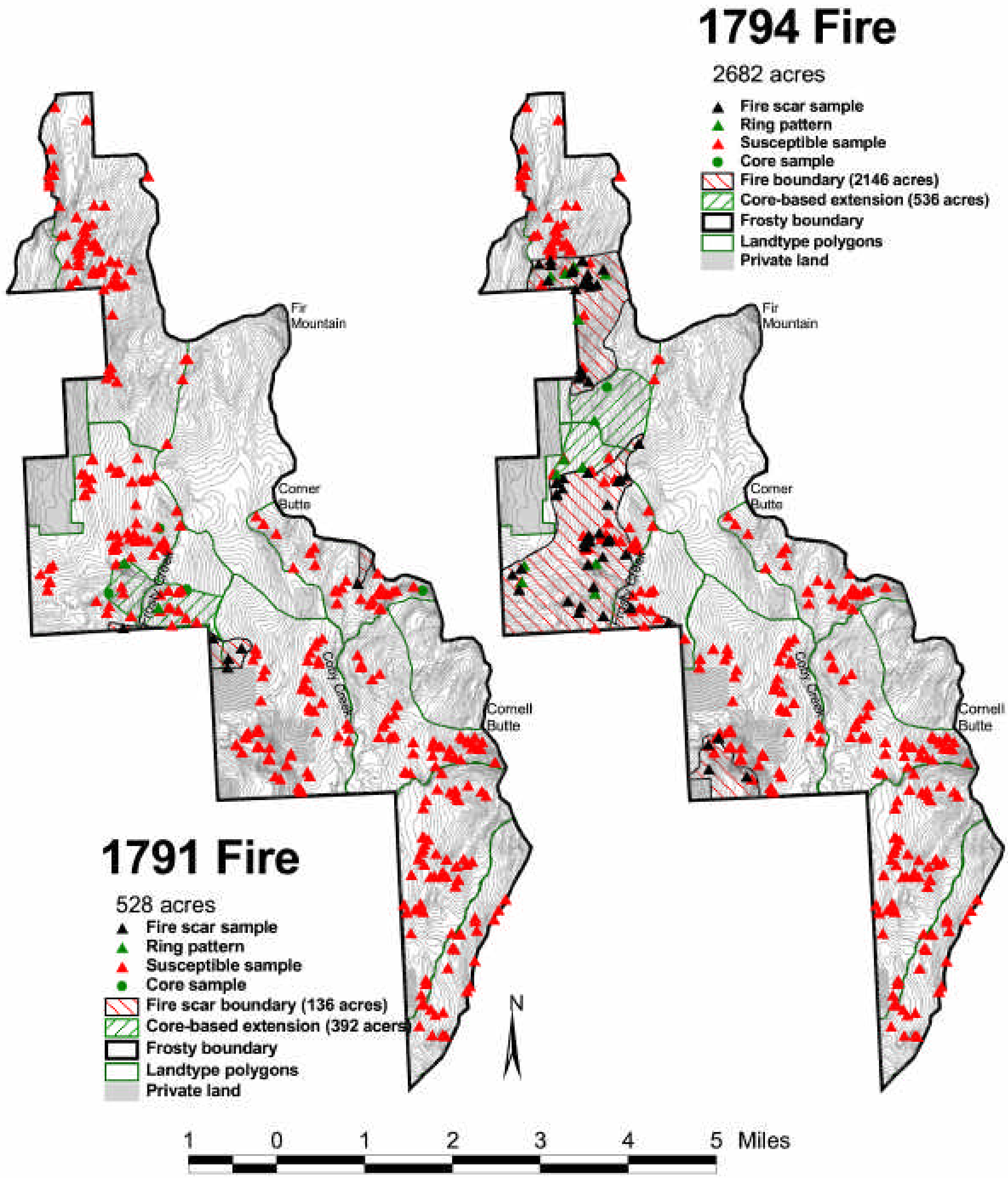

1771 Fire
1153 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1153 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coby Creek
1769 Fire
615 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (465 acres)
Core-based extension (150 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1774 Fire
308 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (272 acres)
Core-based extension (36 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Frosty Creek
Coby Creek
Cornell Butte
1772 Fire
35 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (35 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

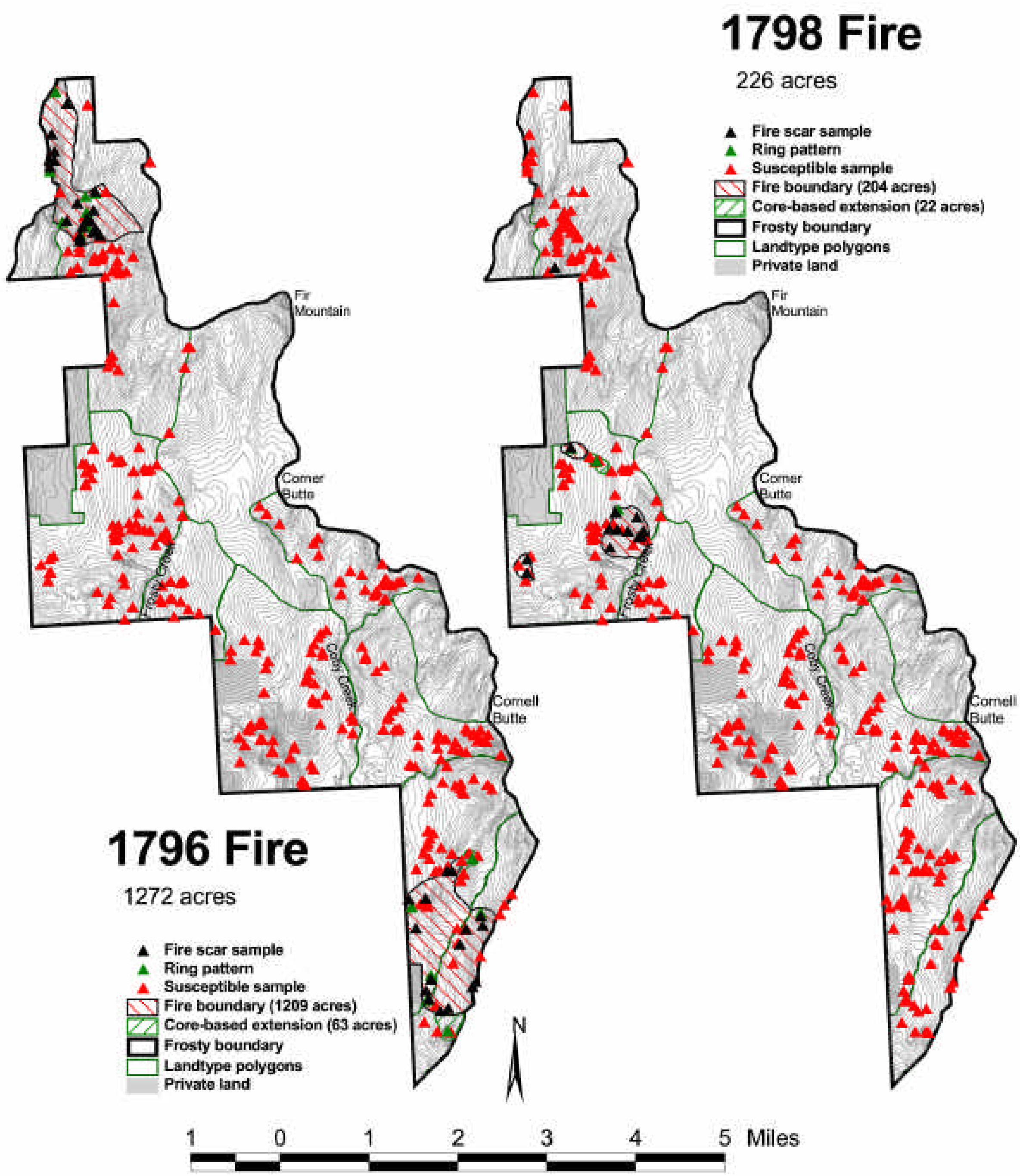

1778 Fire
182 acres
Fire scar sample
Susceptible sample
Fire boundary (182 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coby Creek
1776 Fire
932 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (932 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

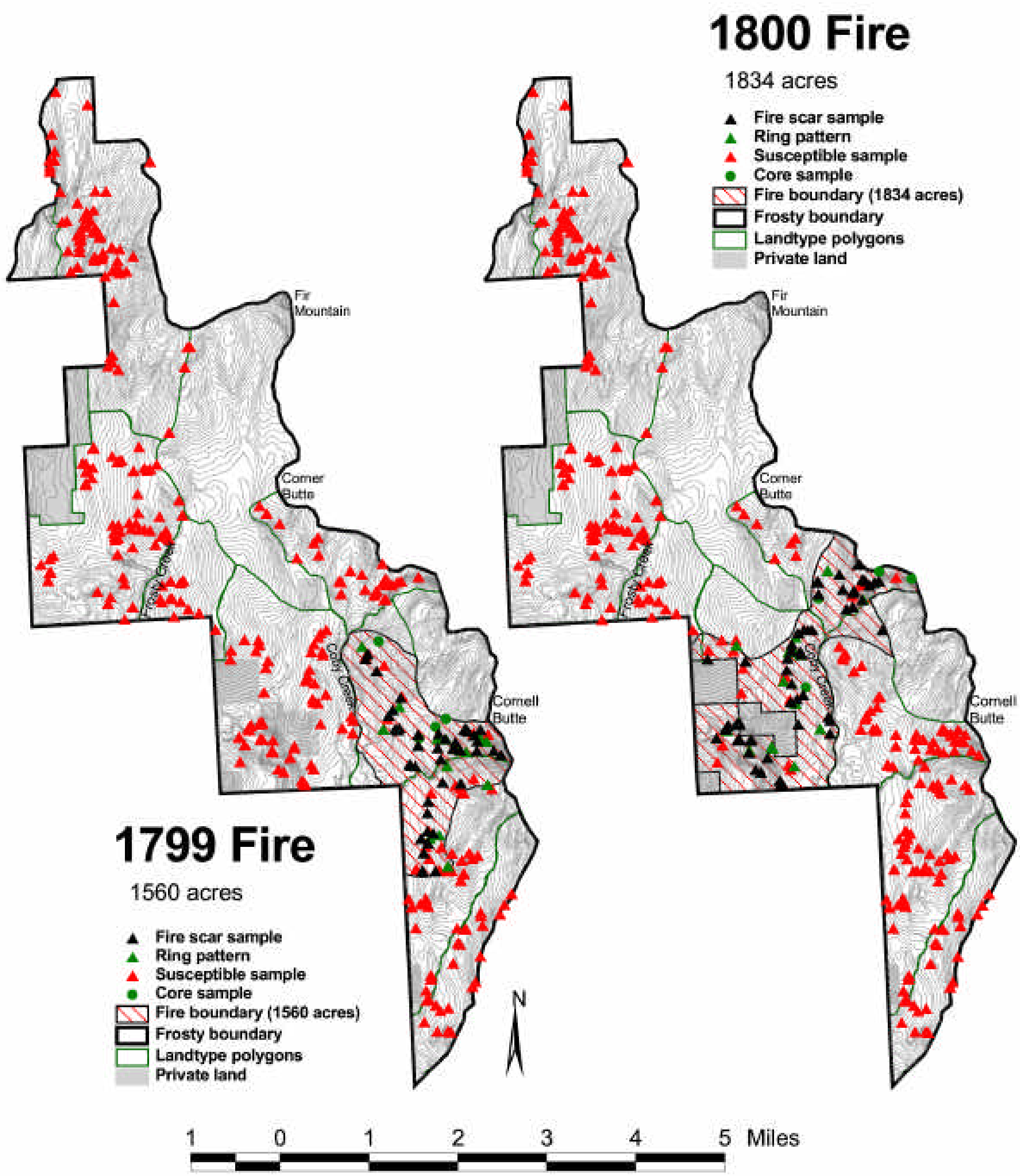


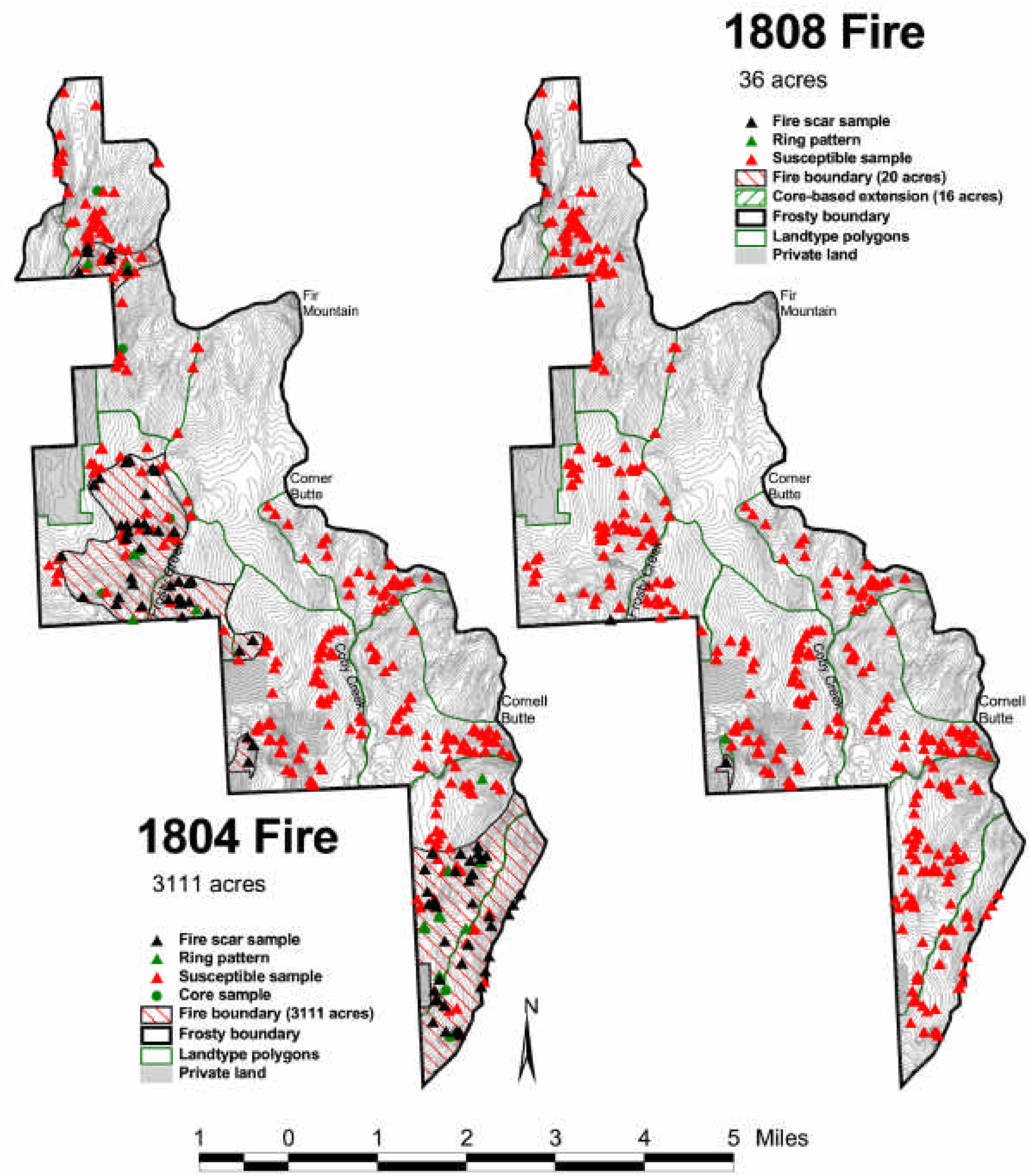
1783 Fire
2236 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2204 acres)
Core-based extension (32 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1781 Fire
5132 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (5132 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

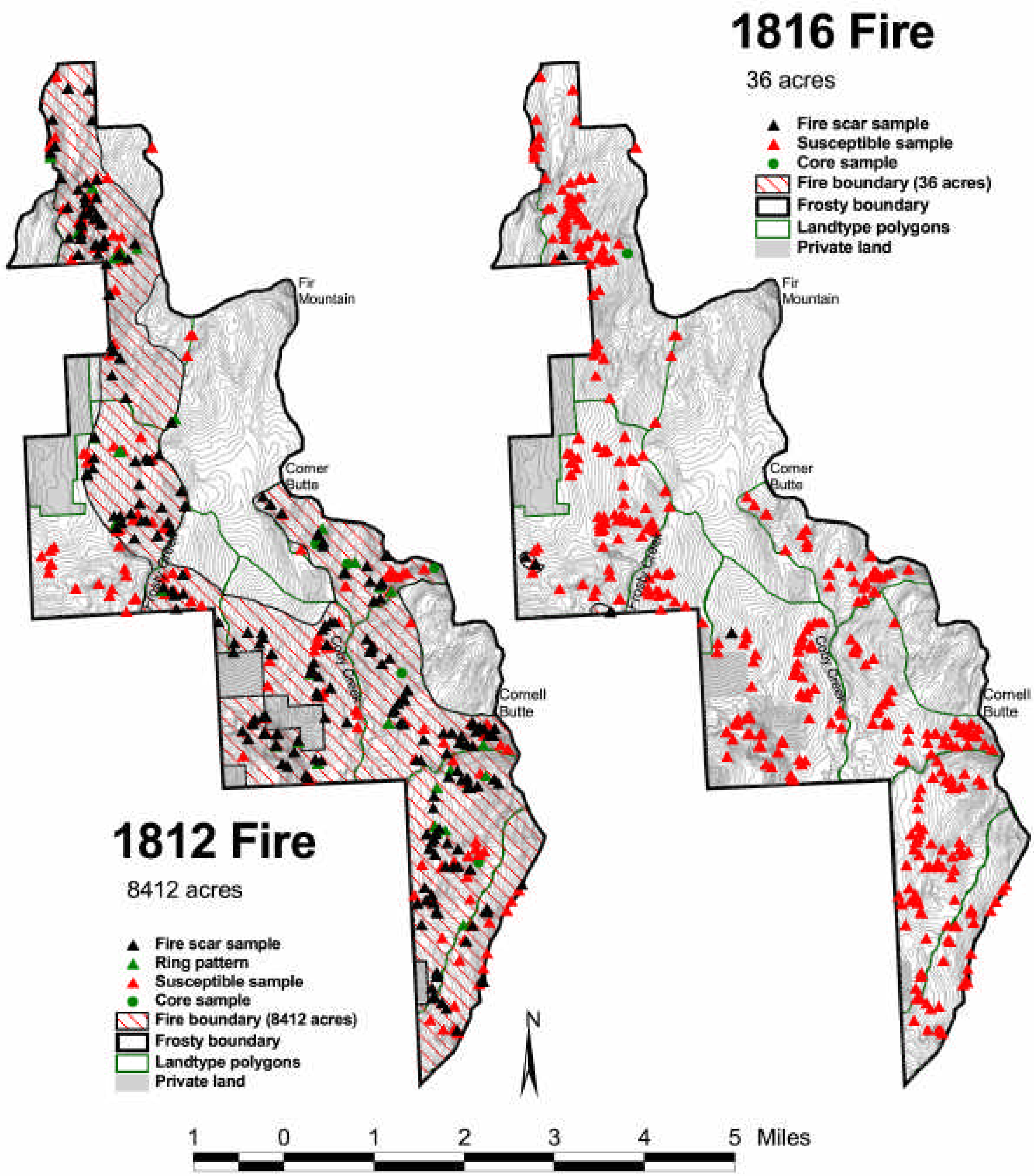


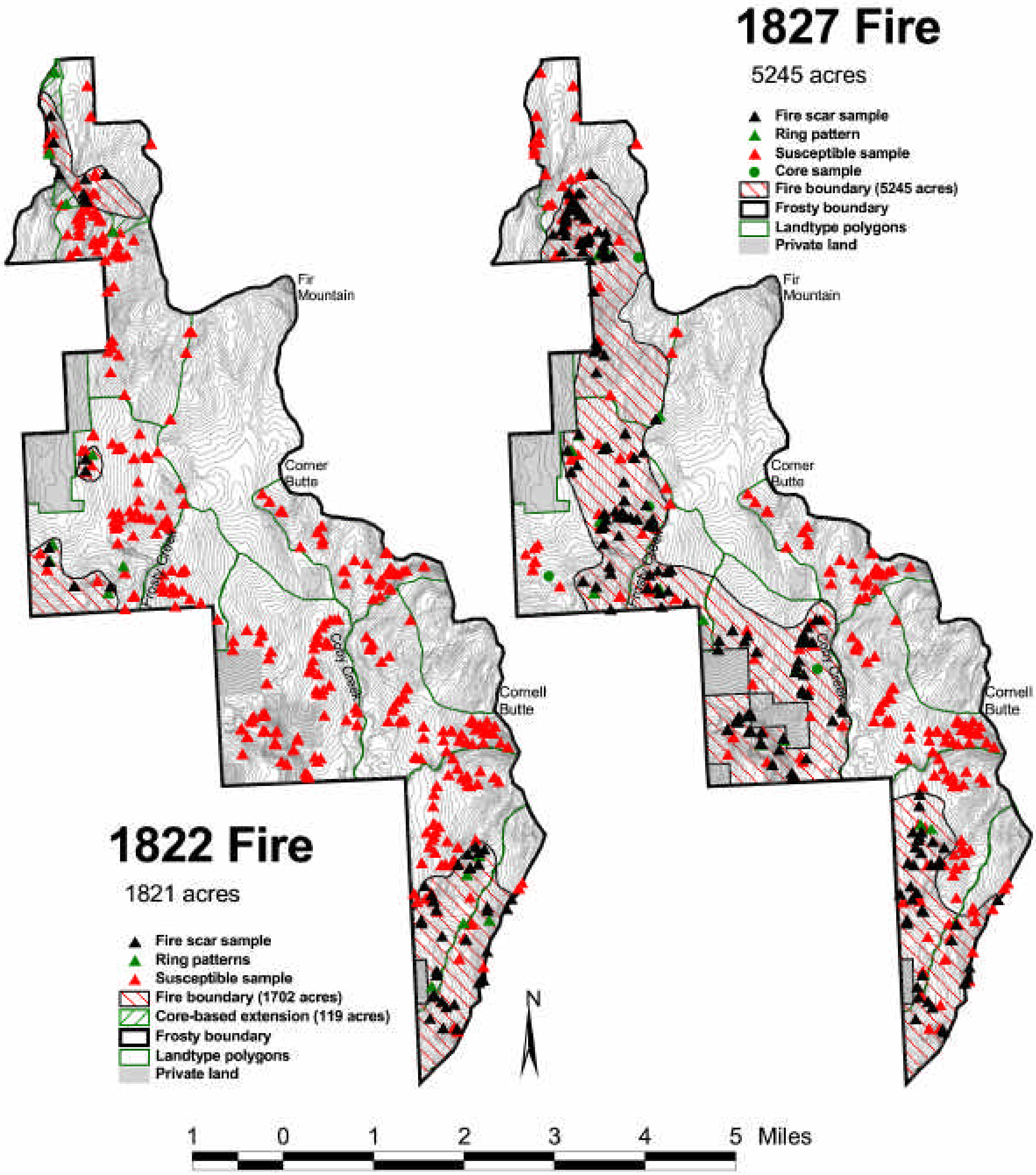
1794 Fire
2682 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2146 acres)
Core-based extension (536 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1791 Fire
528 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire scar boundary (136 acres)
Core-based extension (392 acers)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

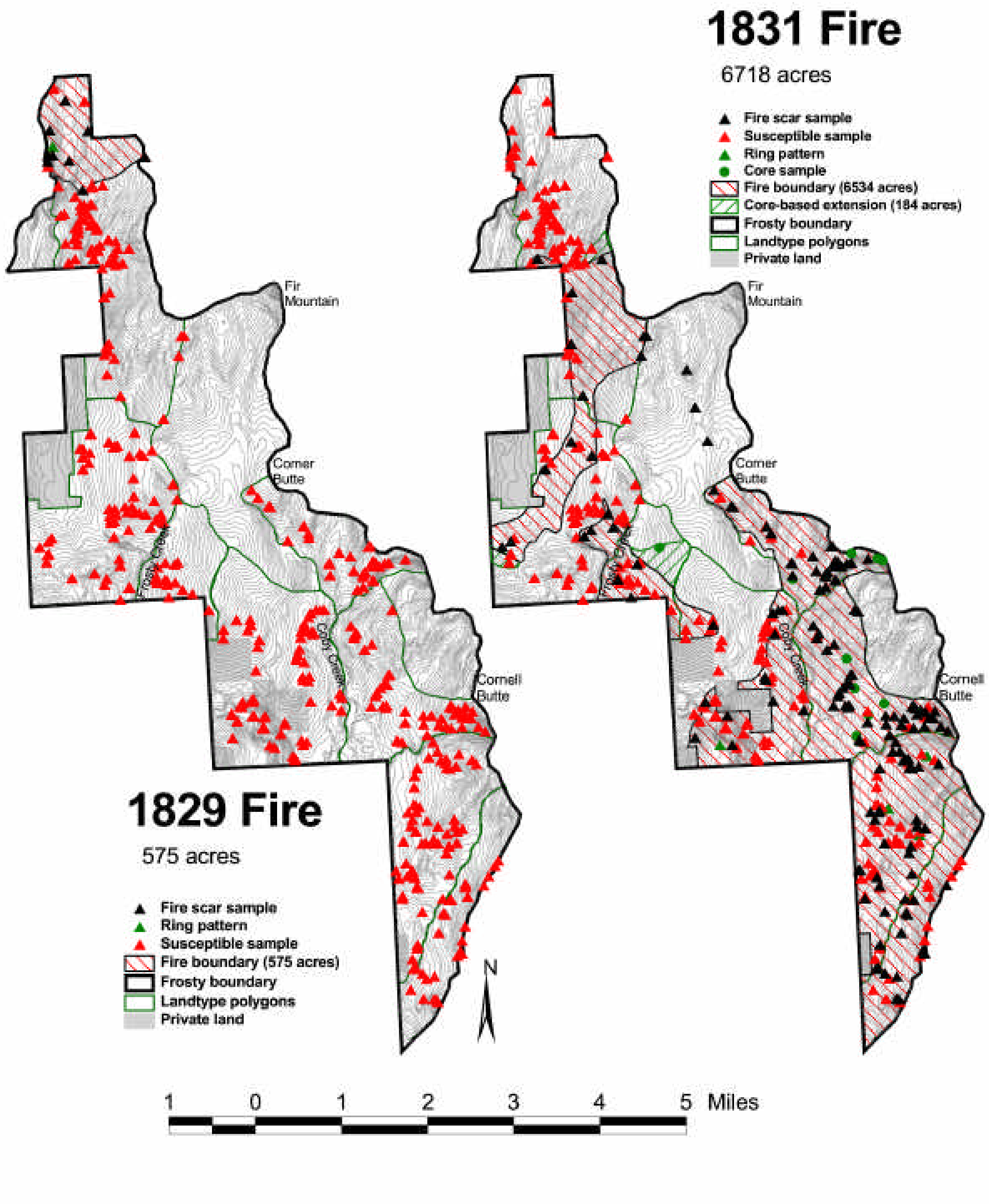

1798 Fire
226 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (204 acres)
Core-based extension (22 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cobb Creek
1796 Fire
1272 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (1209 acres)
Core-based extension (63 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1800 Fire
1834 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1834 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Cody Creek
1799 Fire
1560 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1560 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

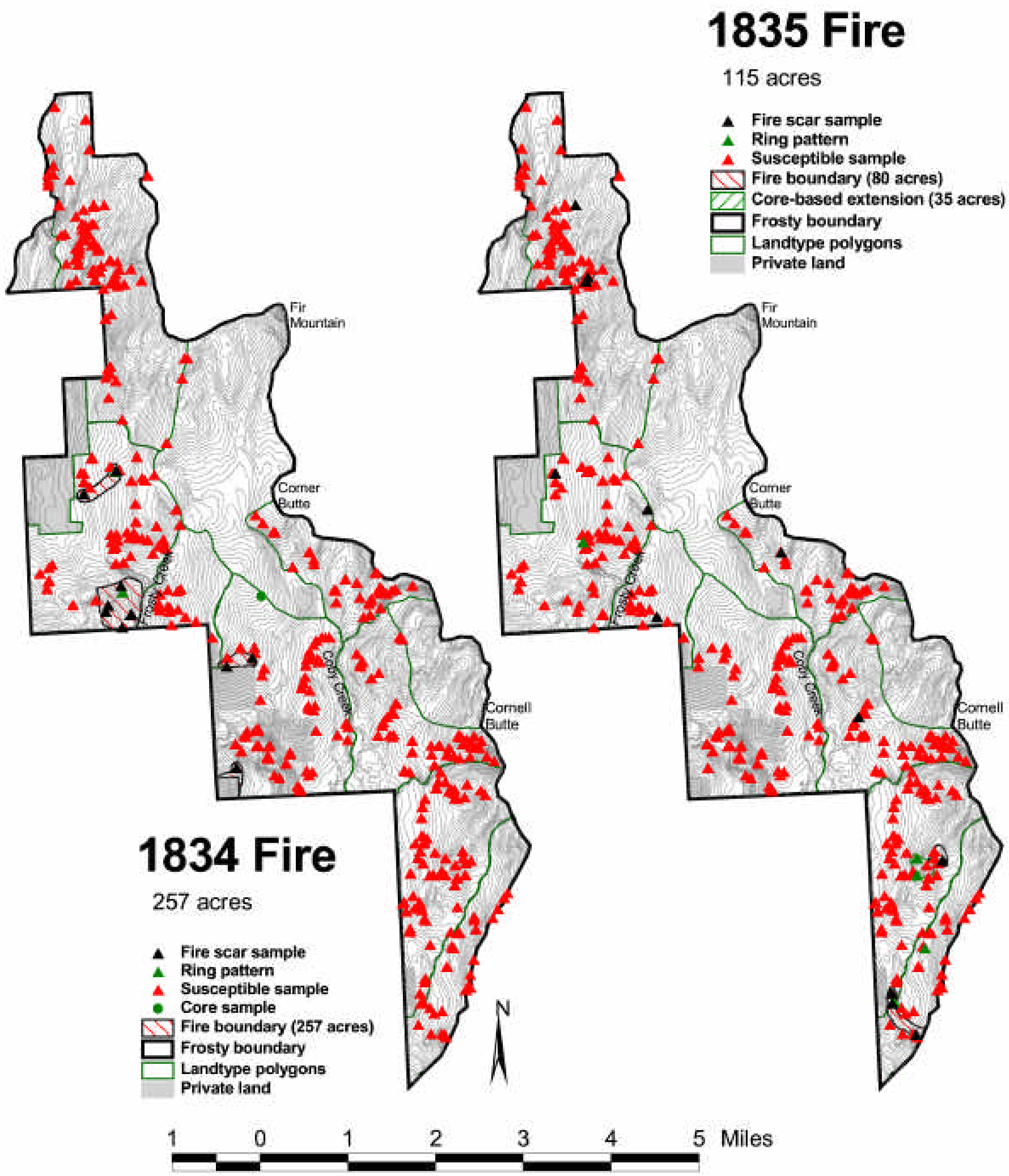

1808 Fire
36 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (20 acres)
Core-based extension (16 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1804 Fire
3111 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (3111 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

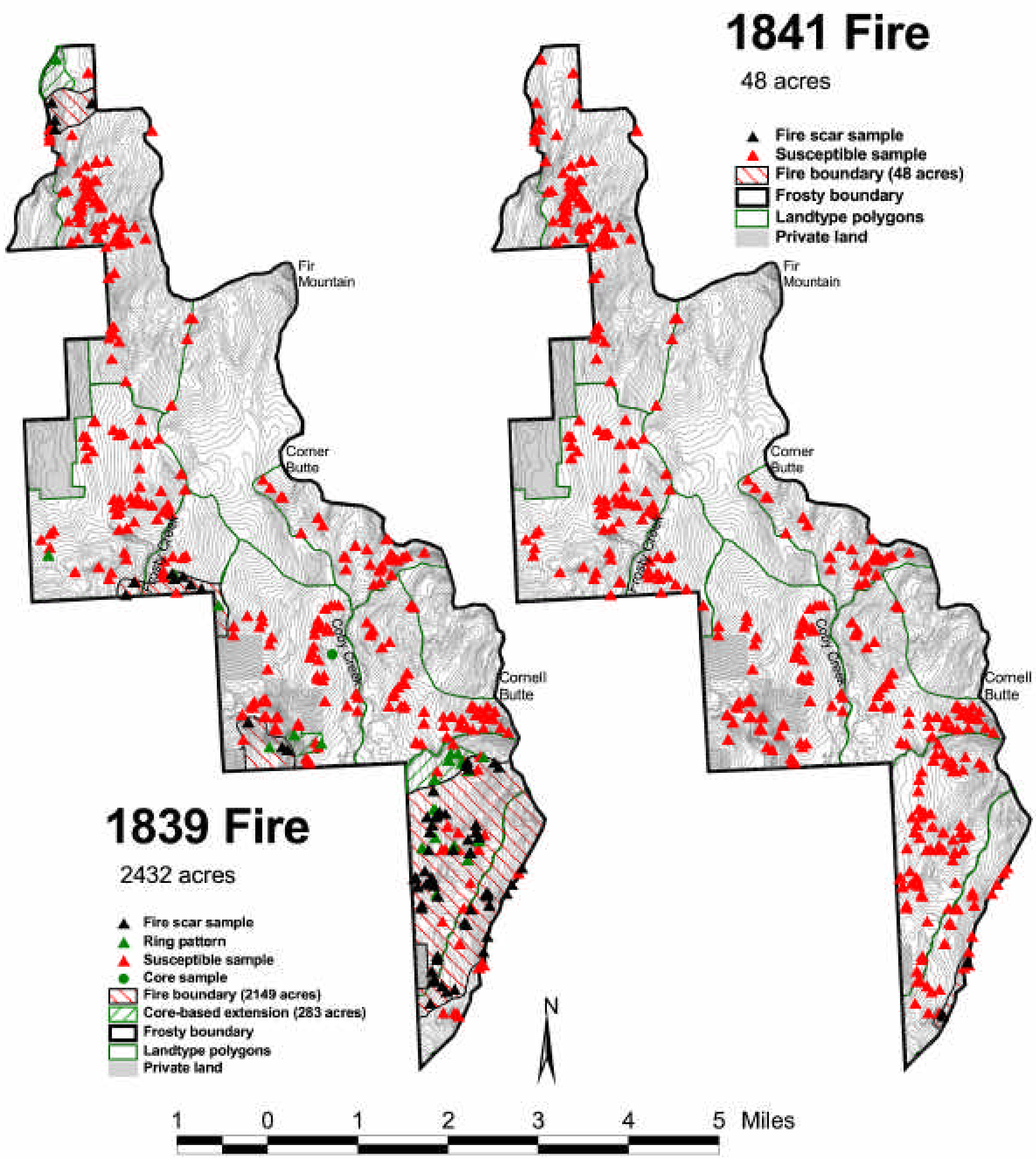

1816 Fire
36 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (36 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cobb Creek
1812 Fire
8412 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (8412 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

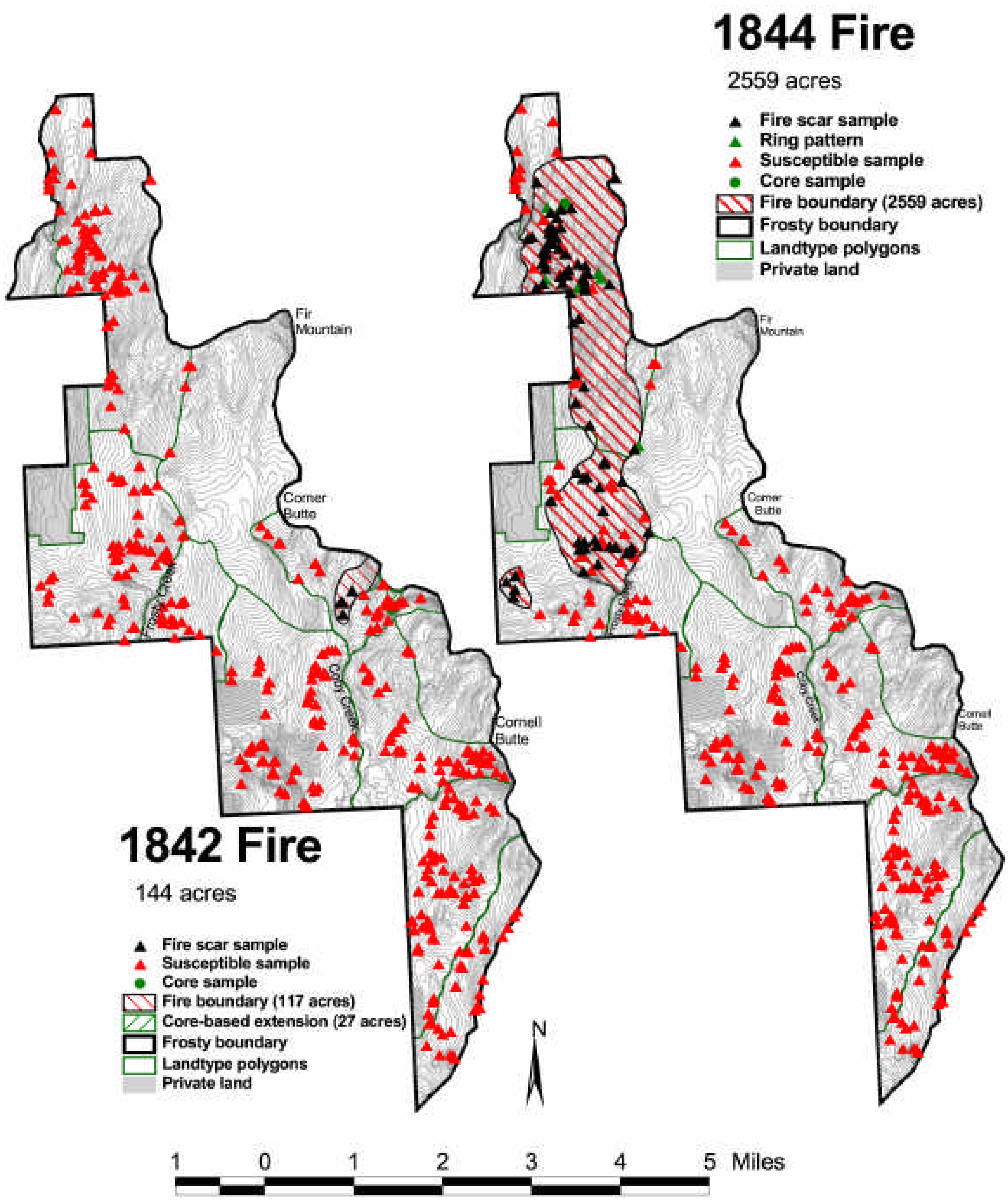

1827 Fire
5245 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (5245 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cody Creek
1822 Fire
1821 acres
Fire scar sample
Ring patterns
Susceptible sample
Fire boundary (1702 acres)
Core-based extension (119 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles



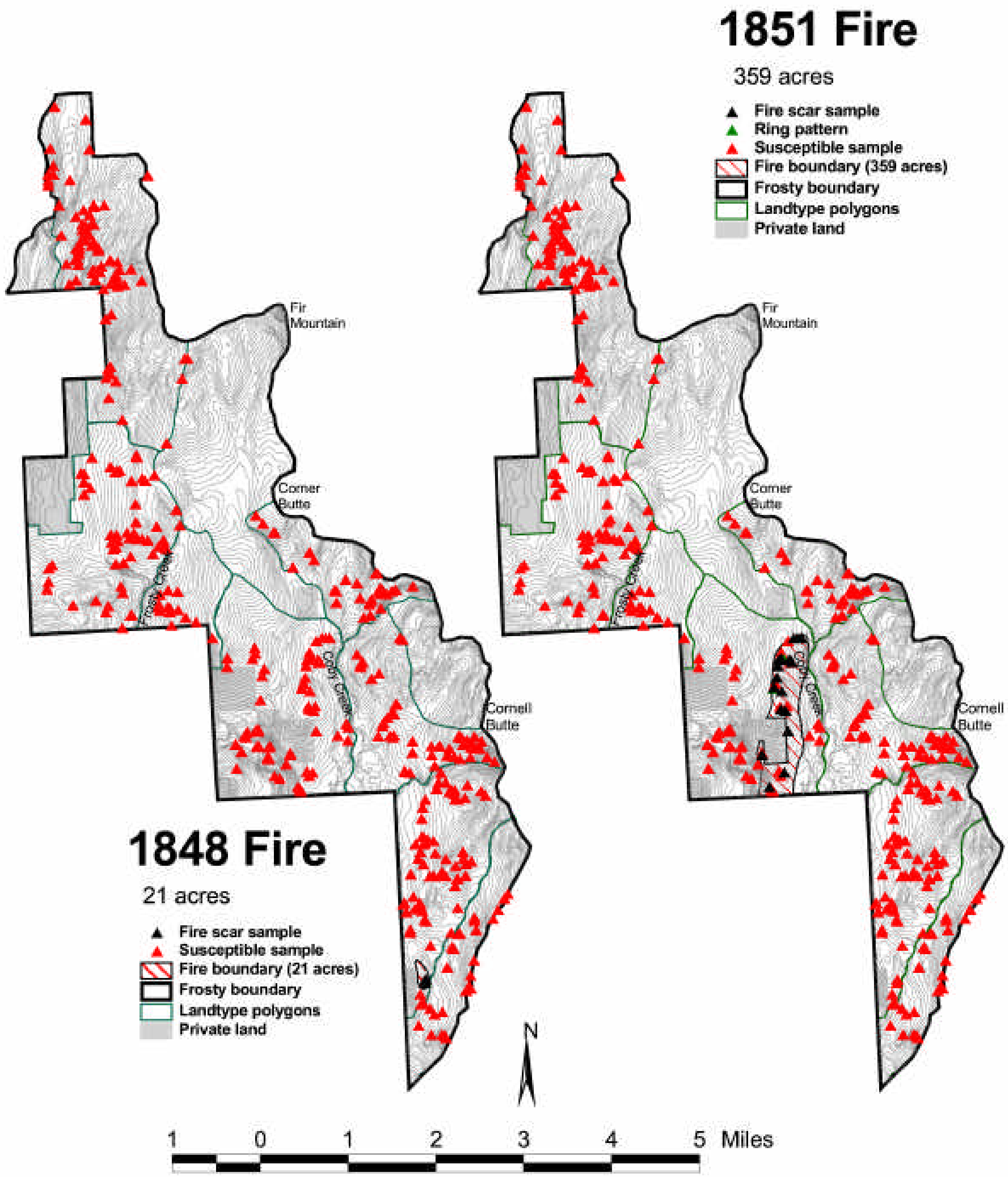
1831 Fire
6718 acres
Fire scar sample
Susceptible sample
Ring pattern
Core sample
Fire boundary (6534 acres)
Core-based extension (184 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Corn Creek
1829 Fire
575 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (575 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1835 Fire
115 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (80 acres)
Core-based extension (35 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Coon Creek
1834 Fire
257 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (257 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

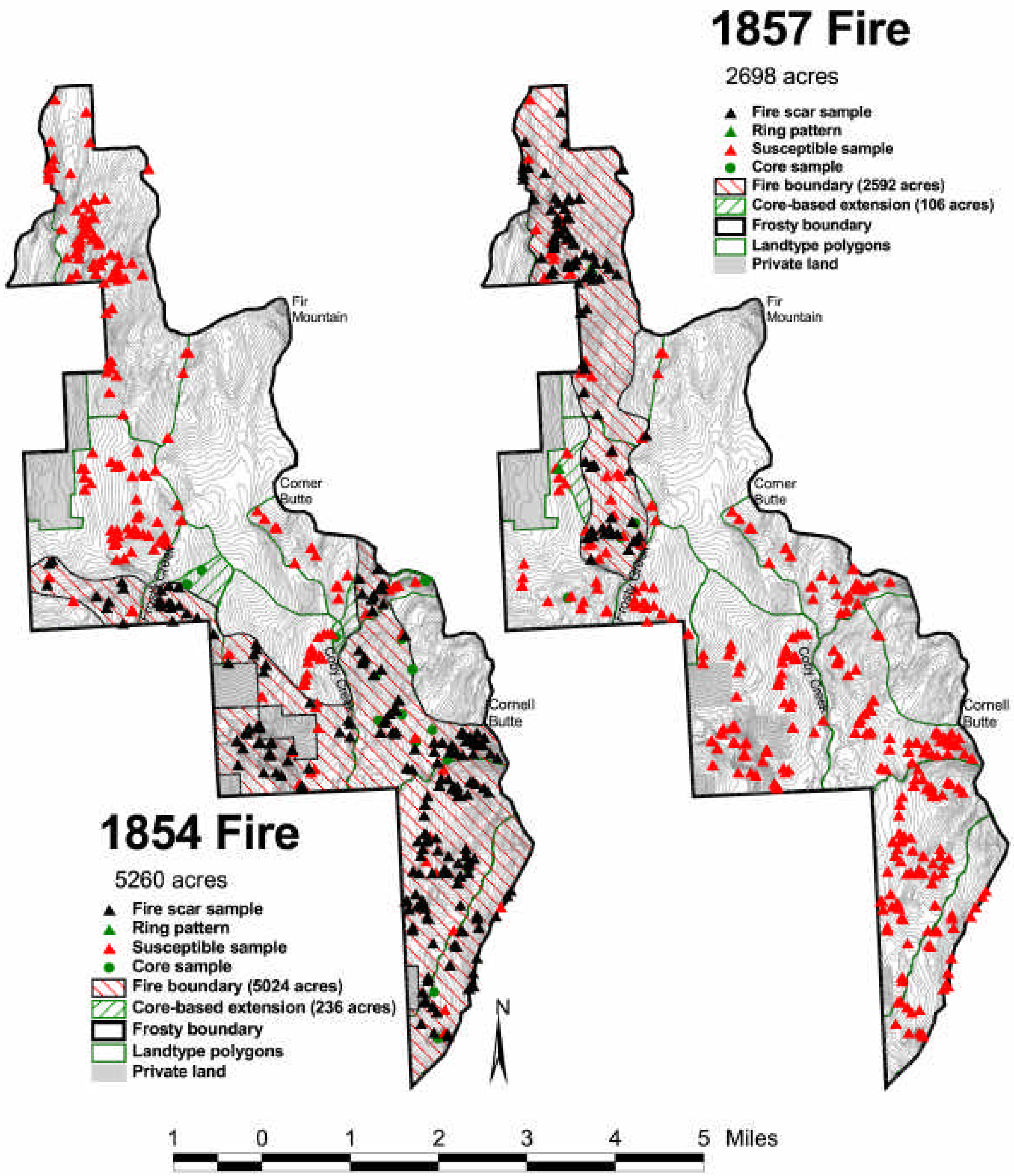

1841 Fire
48 acres
Fire scar sample
Susceptible sample
Fire boundary (48 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Cody Creek
1839 Fire
2432 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2149 acres)
Core-based extension (283 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

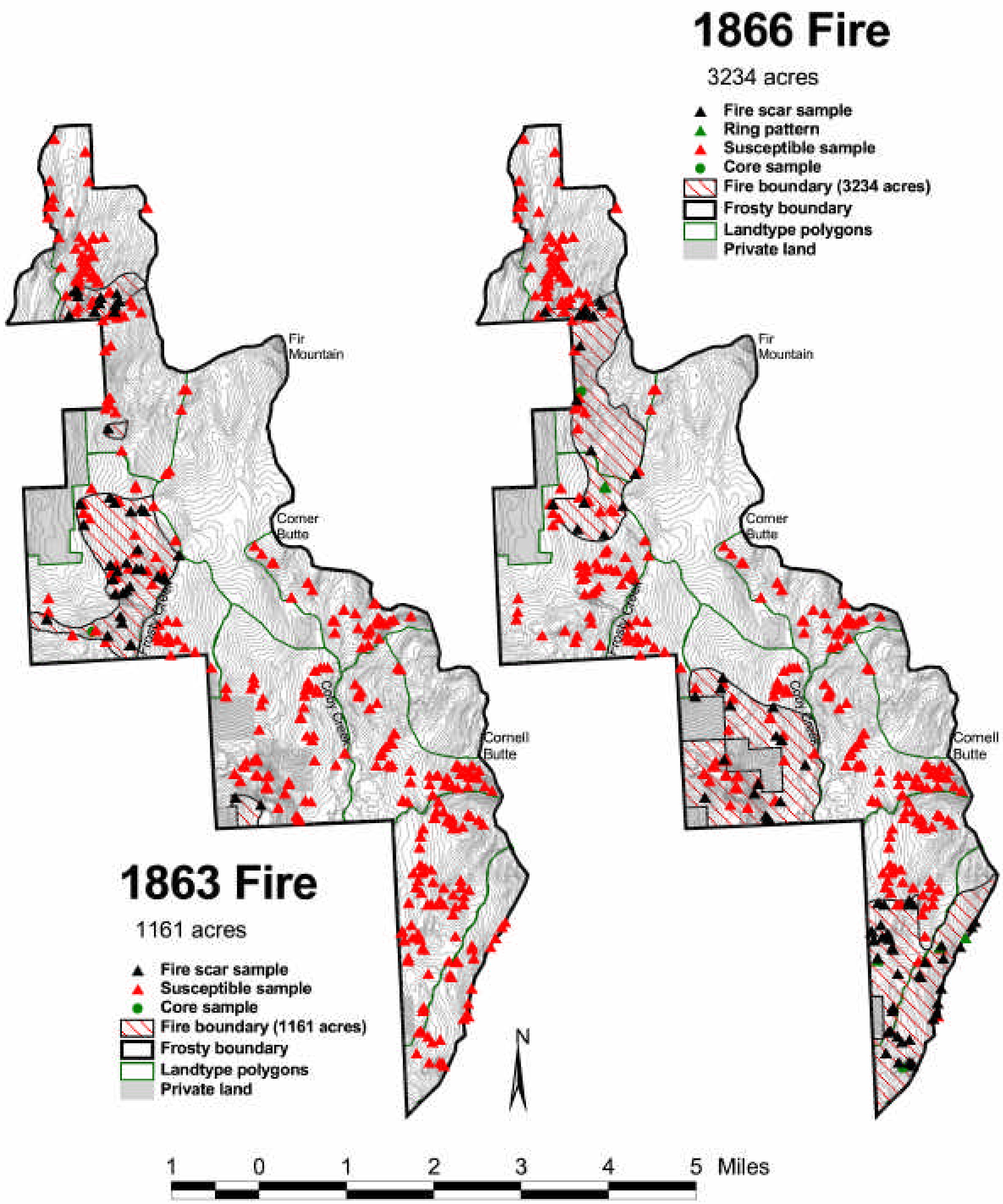


1844 Fire
2559 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2559 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1842 Fire
144 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (117 acres)
Core-based extension (27 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

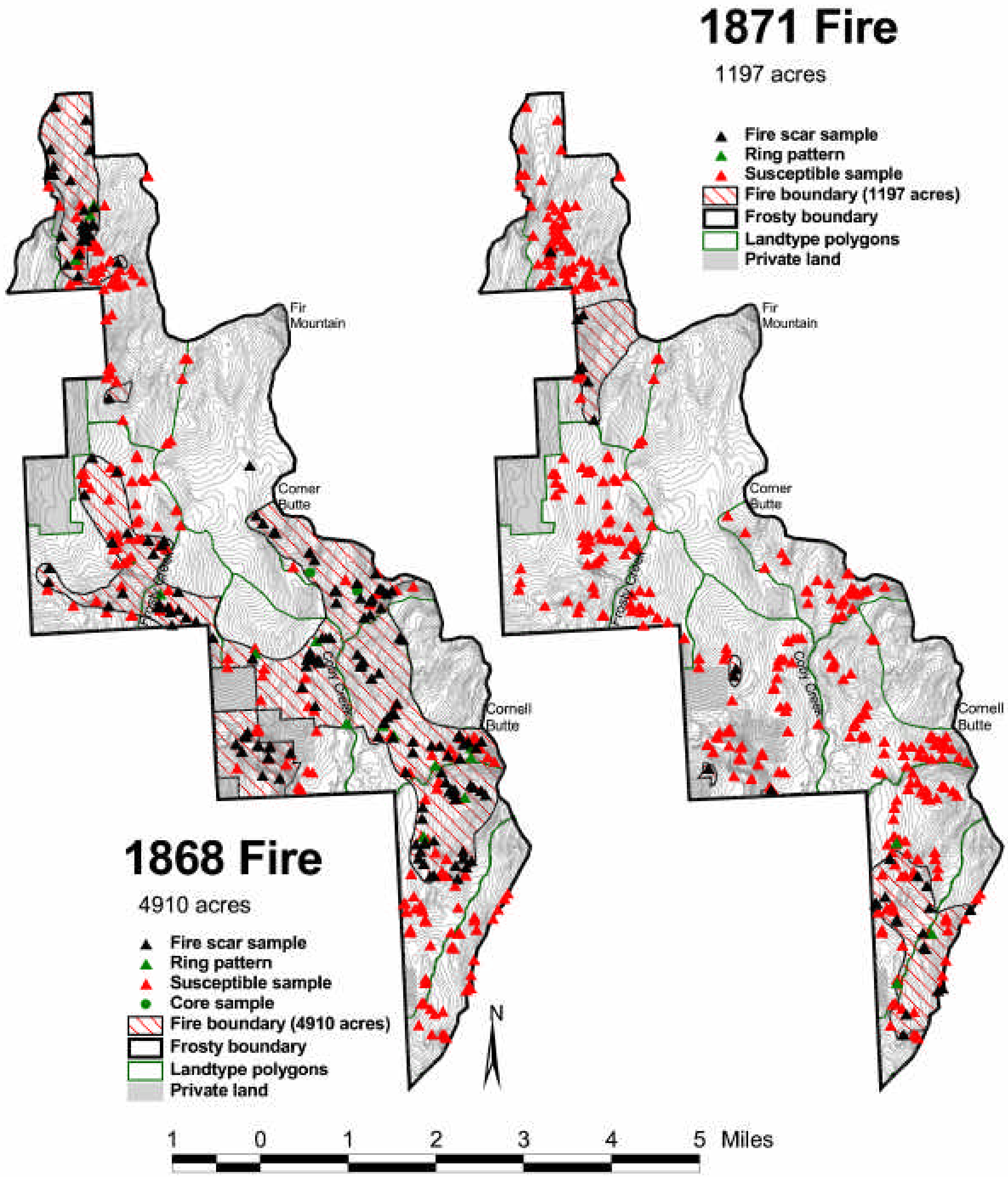


1848 Fire
21 acres
Fire scar sample
Susceptible sample
Fire boundary (21 acres)
Frosty boundary
Landtype polygons
Private land
1851 Fire
359 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (359 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Coon Creek
N
1 0 1 2 3 4 5 Miles

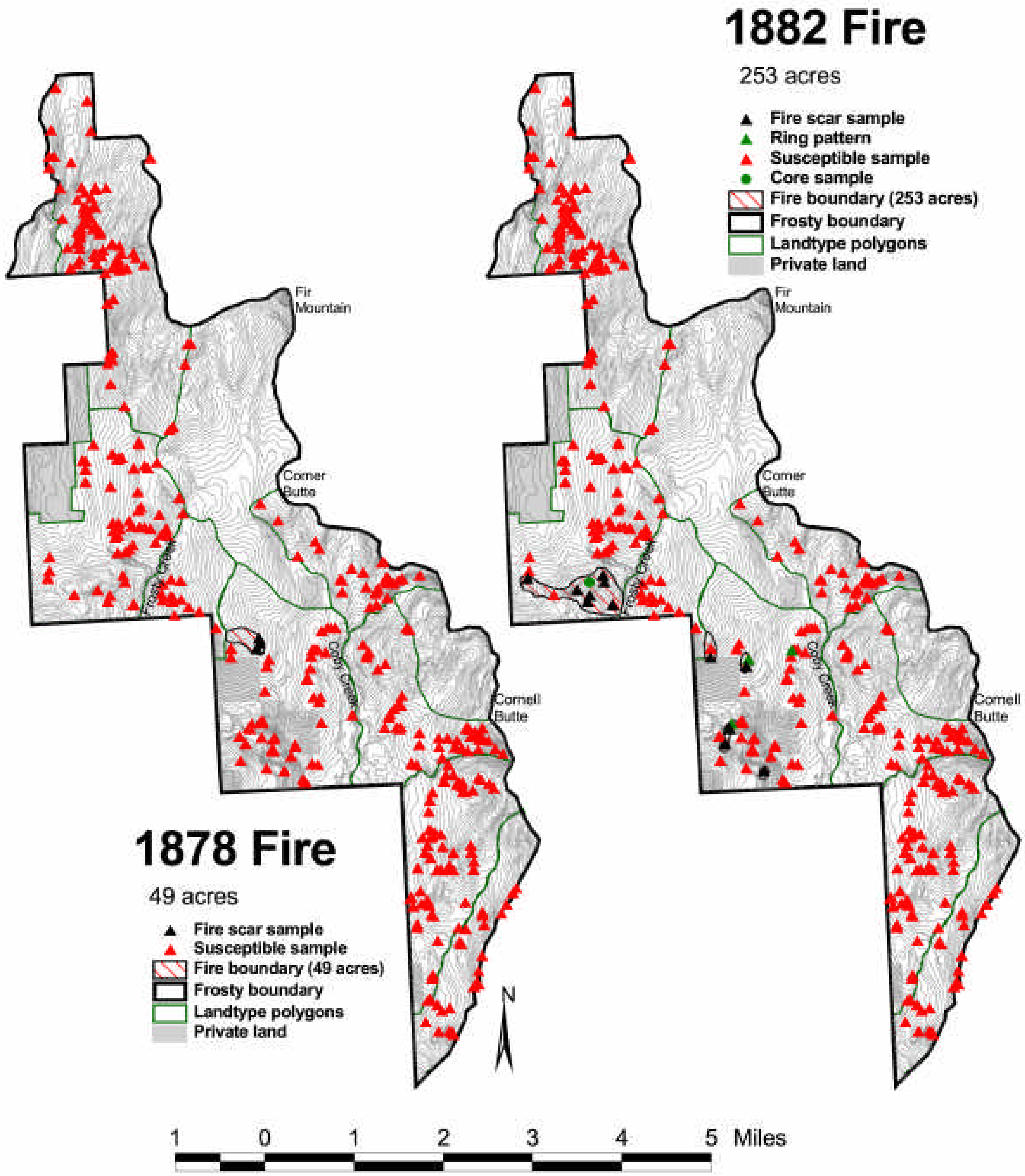

1857 Fire
2698 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2592 acres)
Core-based extension (106 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Coon Creek
1854 Fire
5260 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (5024 acres)
Core-based extension (236 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

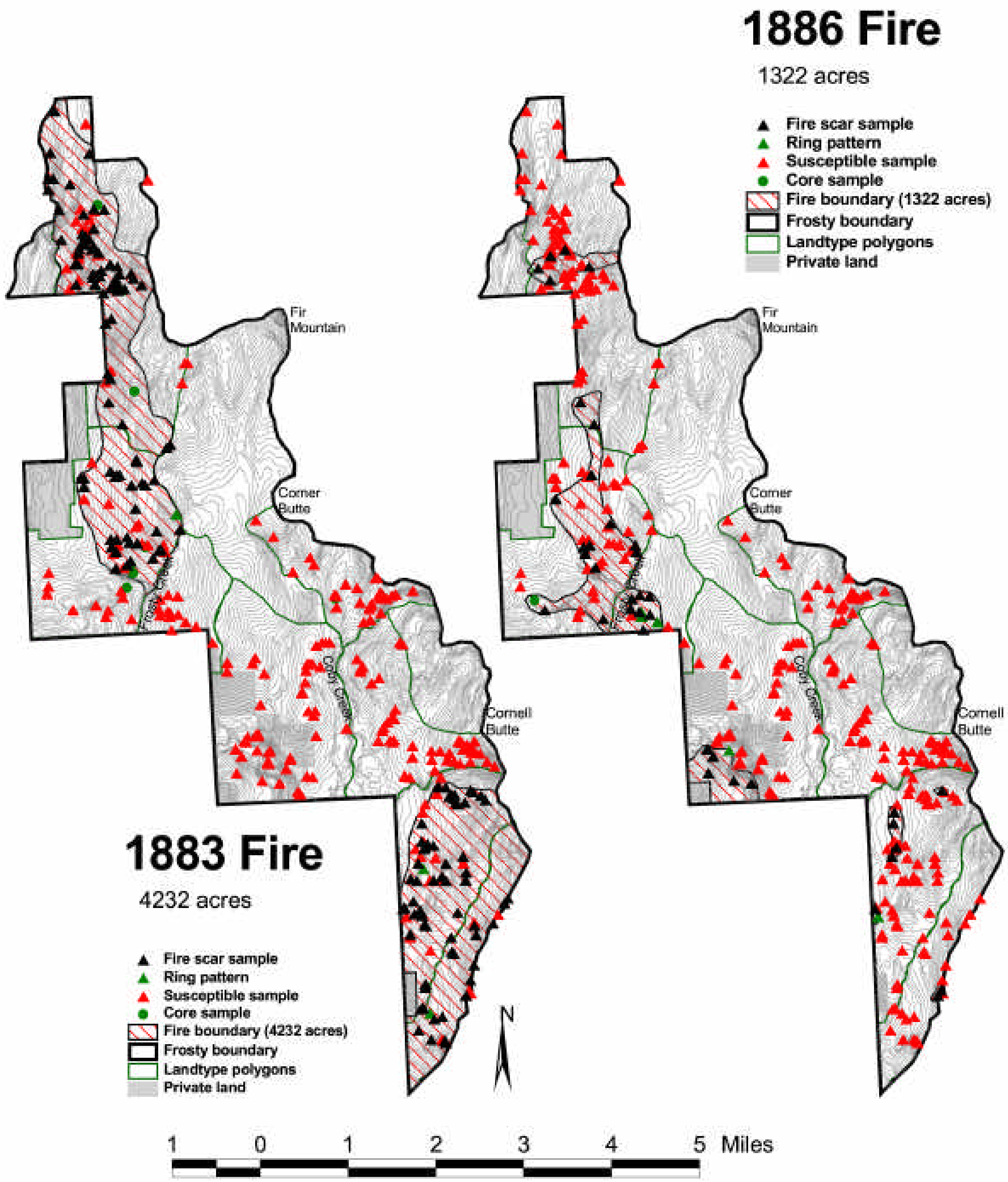


1866 Fire
3234 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (3234 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Coon Creek
1863 Fire
1161 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (1161 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

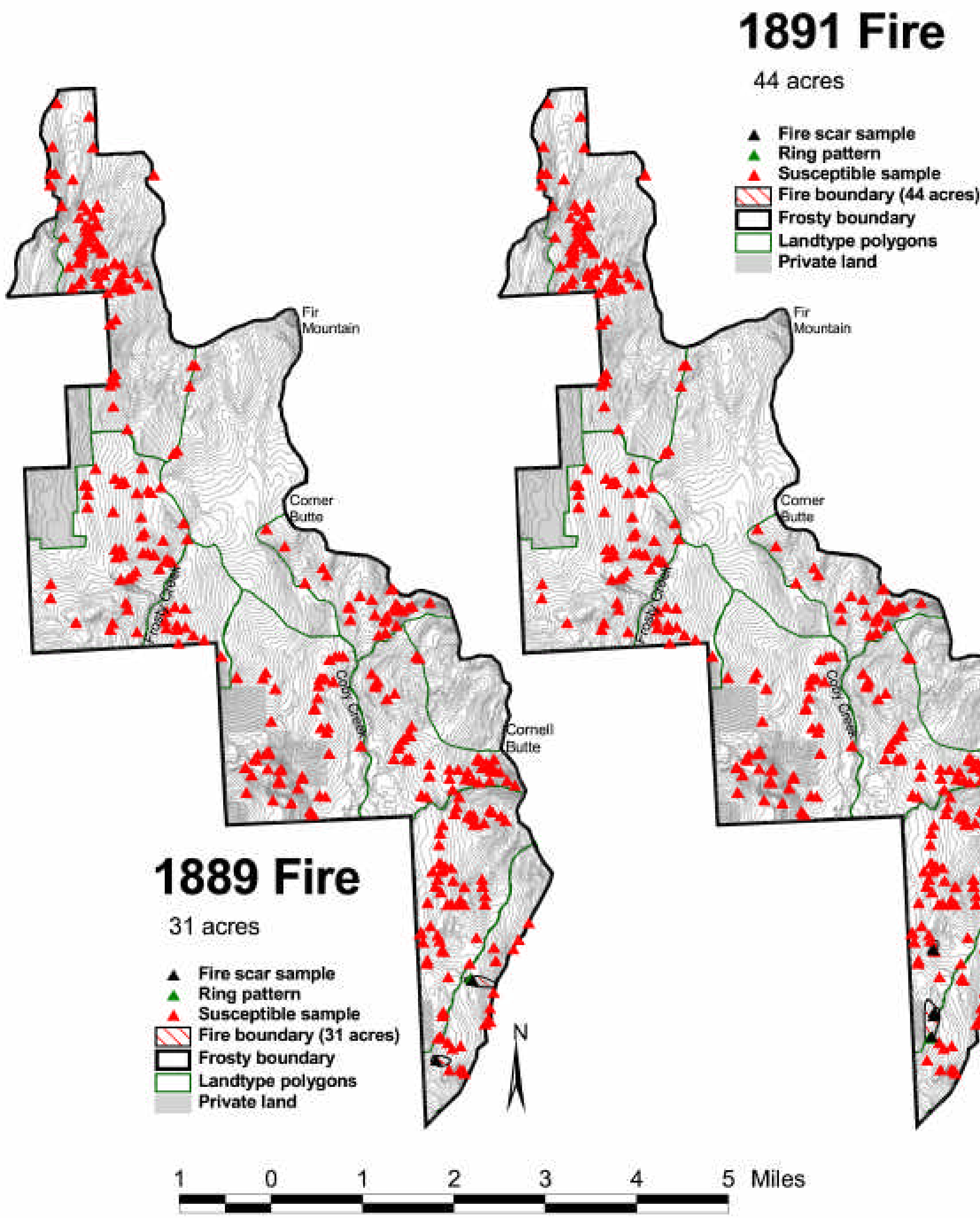


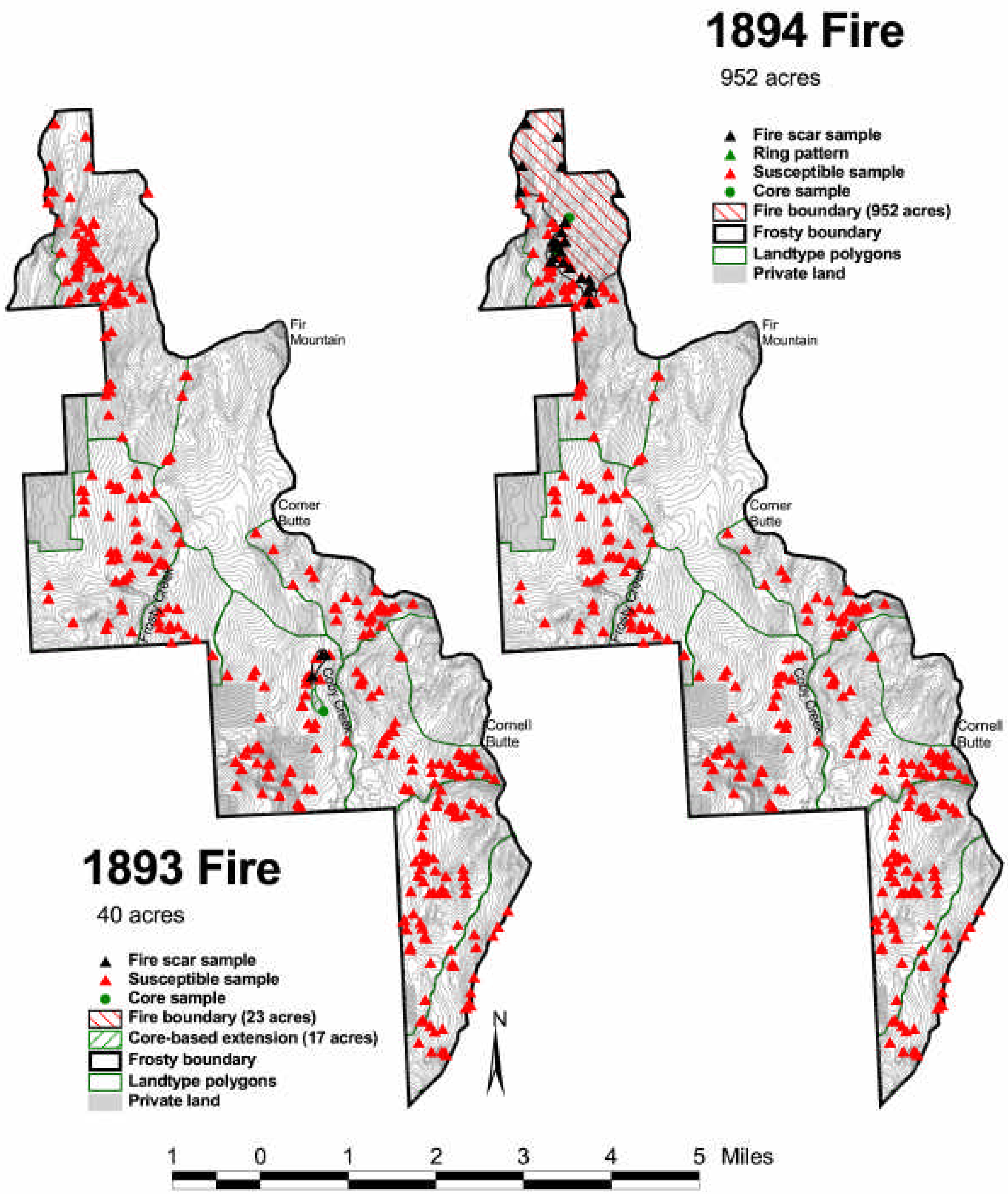
1871 Fire
1197 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (1197 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
1868 Fire
4910 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (4910 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

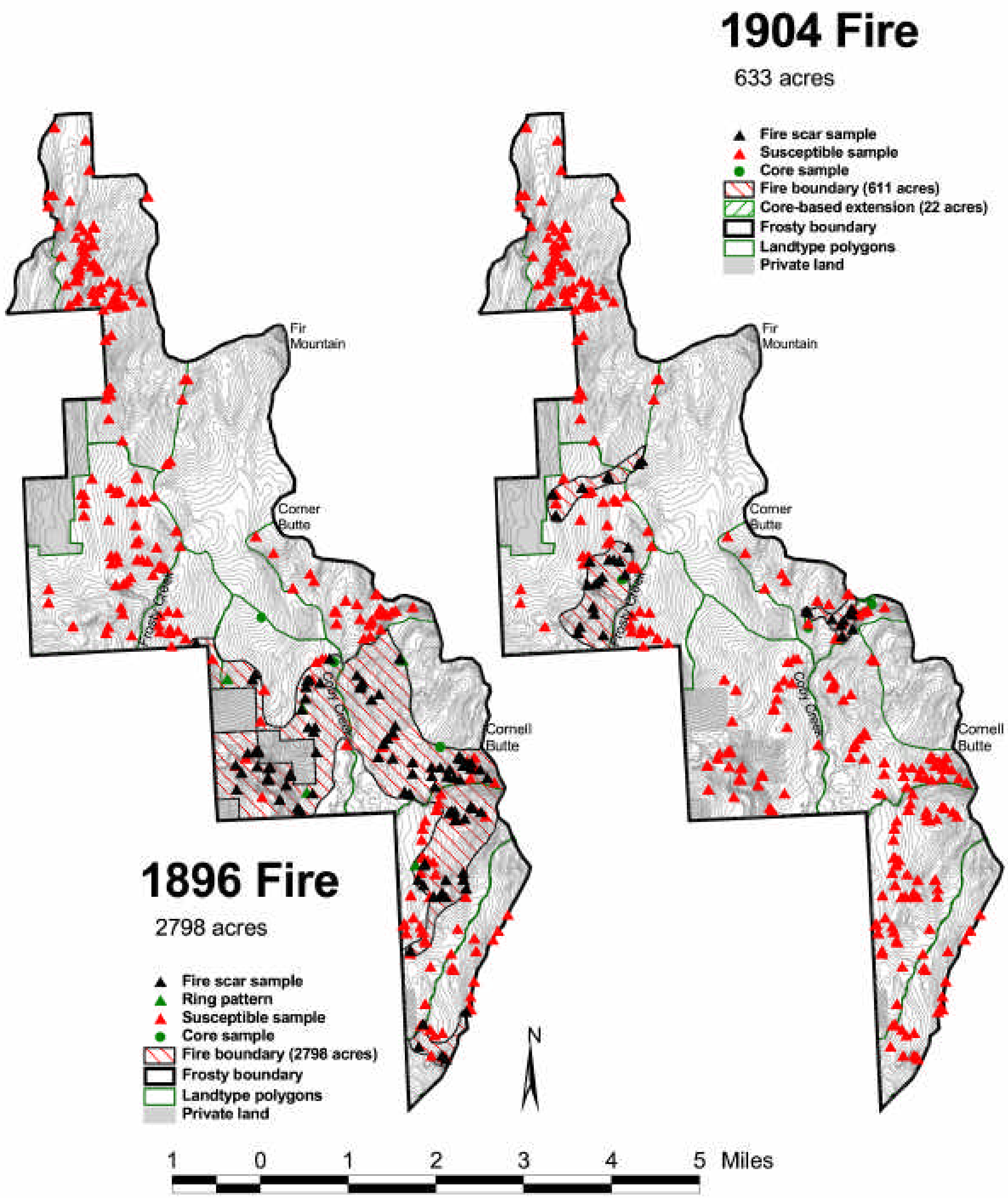

1878 Fire
49 acres
Fire scar sample
Susceptible sample
Fire boundary (49 acres)
Frosty boundary
Landtype polygons
Private land
1882 Fire
253 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (253 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
N
1 0 1 2 3 4 5 Miles

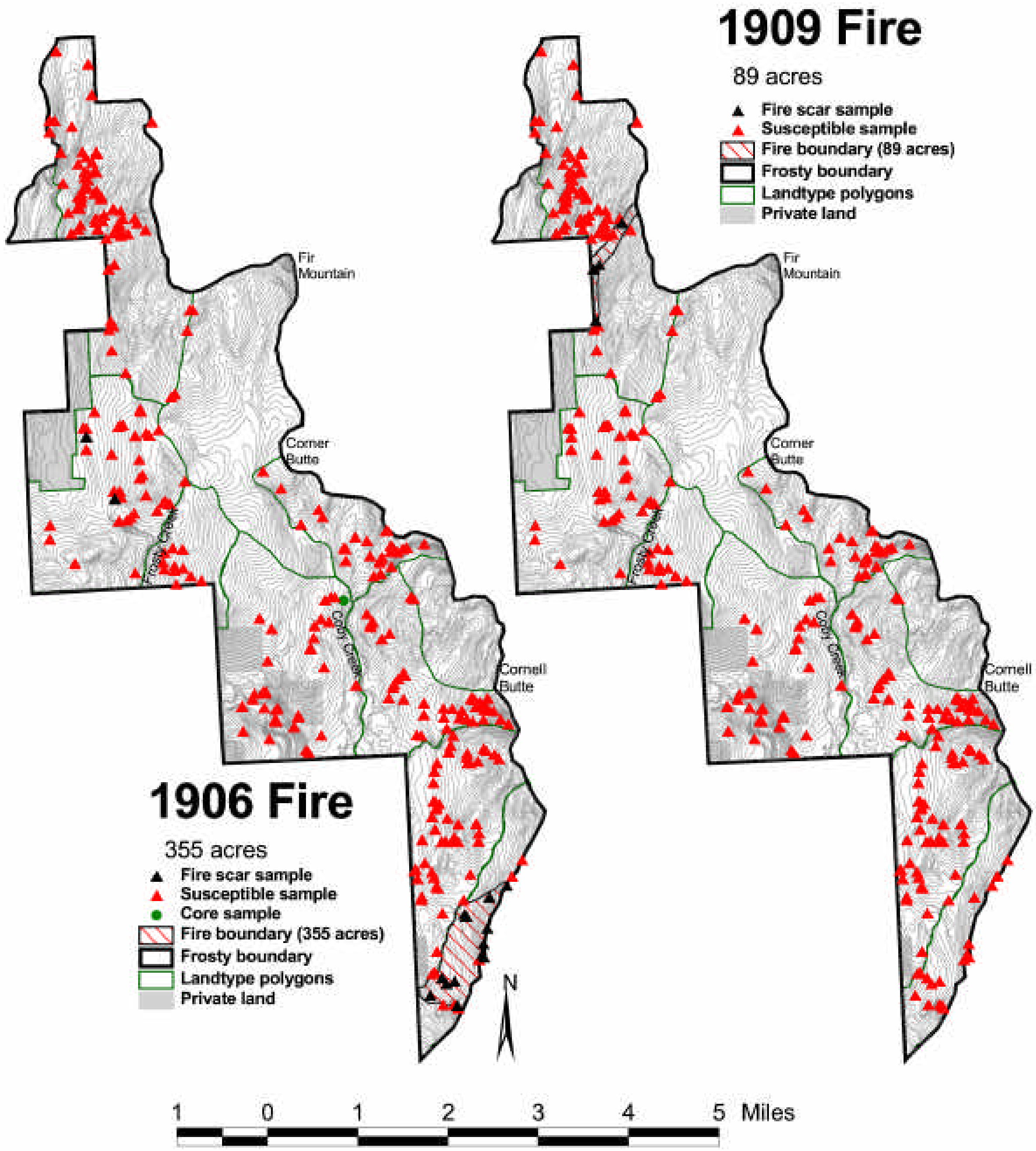


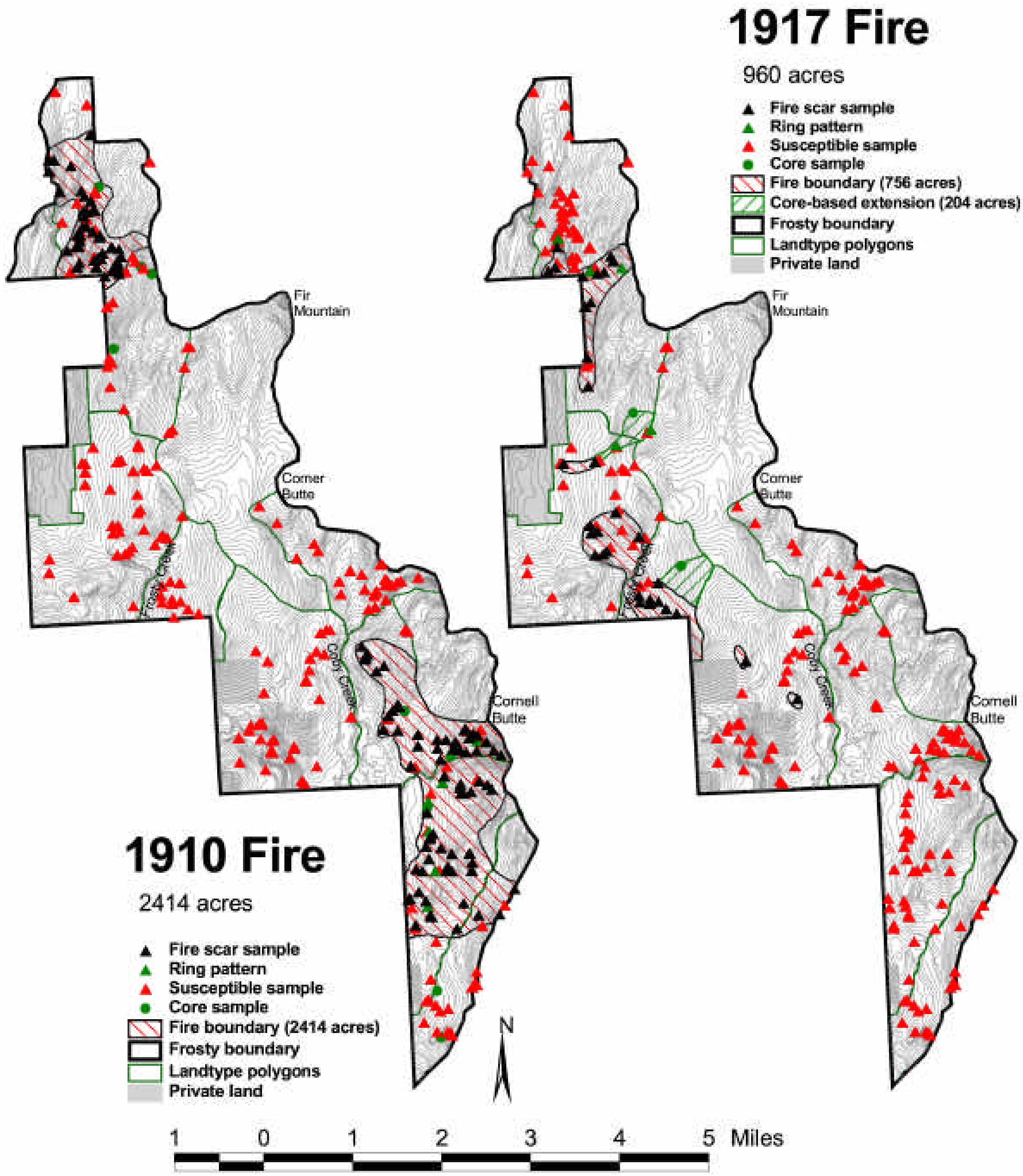
1886 Fire
1322 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (1322 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Coon Creek
1883 Fire
4232 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (4232 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1891 Fire
44 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (44 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1889 Fire
31 acres
Fire scar sample
Ring pattern
Susceptible sample
Fire boundary (31 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles

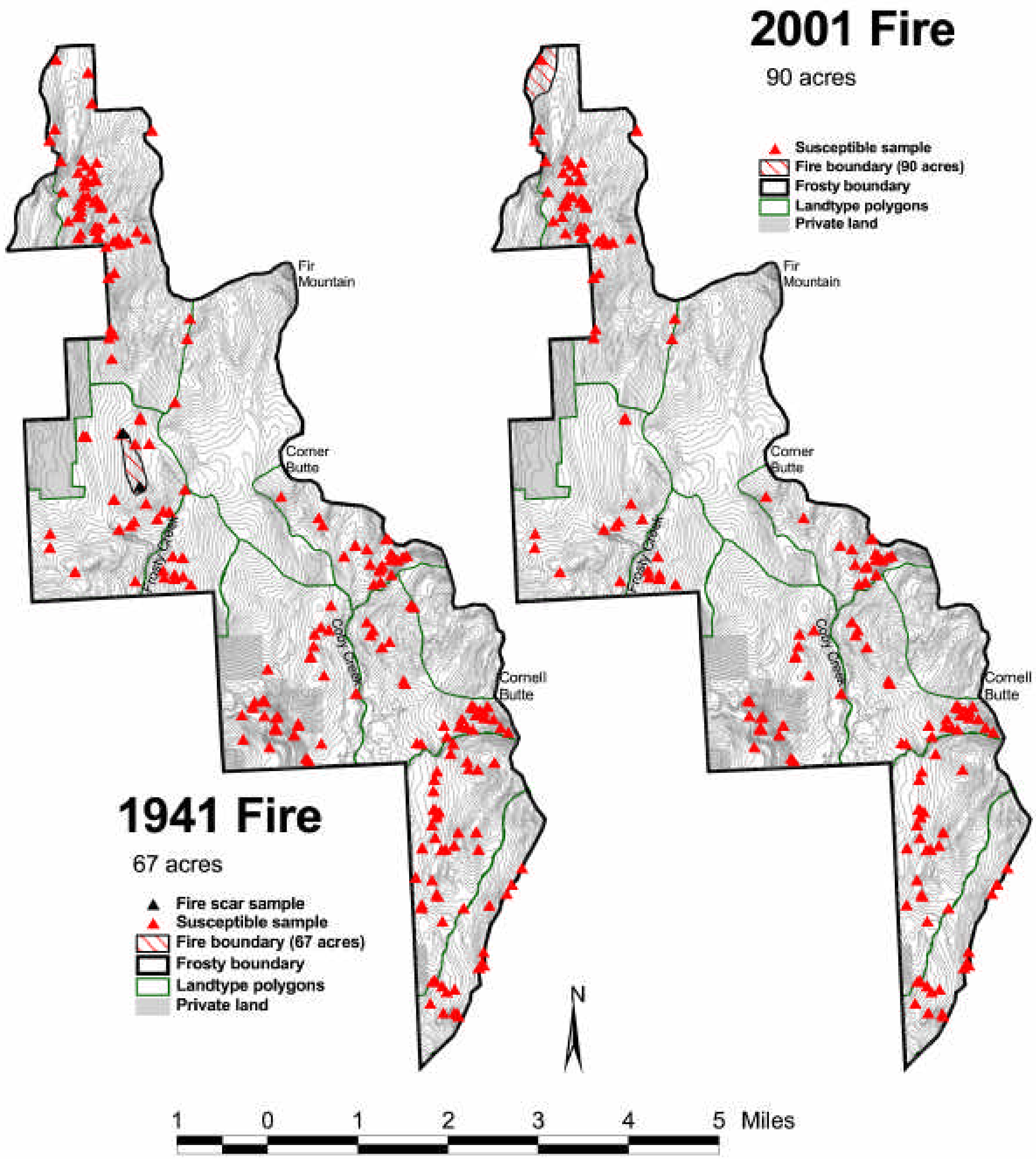

1894 Fire
952 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (952 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1893 Fire
40 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (23 acres)
Core-based extension (17 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1904 Fire
633 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (611 acres)
Core-based extension (22 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
1896 Fire
2798 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2798 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


1909 Fire
89 acres
Fire scar sample
Susceptible sample
Fire boundary (89 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1906 Fire
355 acres
Fire scar sample
Susceptible sample
Core sample
Fire boundary (355 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles



1917 Fire
960 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (756 acres)
Core-based extension (204 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1910 Fire
2414 acres
Fire scar sample
Ring pattern
Susceptible sample
Core sample
Fire boundary (2414 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles


2001 Fire
90 acres
Susceptible sample
Fire boundary (90 acres)
Frosty boundary
Landtype polygons
Private land
Fir Mountain
Corner Butte
Cornell Butte
Frosty Creek
Coon Creek
1941 Fire
67 acres
Fire scar sample
Susceptible sample
Fire boundary (67 acres)
Frosty boundary
Landtype polygons
Private land
N
1 0 1 2 3 4 5 Miles